THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE IV. VOL. VII.

No. VIII.—AUGUST, 1900.

ORIGINAL ARTICLES.

I.—On the Fauna of the Upper Cassian Zone in Falzarego Valley, South Tyrol.

By M. M. Ogilvie Gordon, D.Sc.

HAVING the opportunity of revisiting Munich, I have drawn up a list of the fossils which formed the basis of the "Upper Cassian Zone," erected by me in 1893. These fossils,[1] when I discovered them in Falzarego Valley in 1891, were then for the most part unknown. The tuffs and breccias in which they occur had been referred by Loretz to the fossiliferous Raibl horizon of the Schlern Plateau, and by Mojsisovics to the much lower horizon of Wengen strata. I found, by careful collection from strata in position, that the fauna, in addition to a fair proportion of St. Cassian types and a few Raibl types, comprised a number of types common both to Cassian and Raibl horizons and a still greater number of species which had not been found elsewhere (Q.J.G.S., 1893, pp. 31, 44, 46, 47).

Judging both from the transitional Cassian-Raibl character of the fauna and from the stratigraphical position of the fossiliferous series in the field, above a zone containing typical St. Cassian fauna, I concluded that this Falzarego Valley fauna represented a palæontological zone younger than the typical St. Cassian fauna as known at Stuores and Prelongei, and older than the lower Raibl fauna as known at Schlern Plateau and described by von Wöhrmann and Koken.[2] I therefore placed it as an independent palæontological zone, naming it Upper Cassian.[3] This determination of an Upper Cassian zone in South Tyrol practically demonstrated the same gradual faunistic transition from Cassian to Raibl zones in South Tyrol which had been demonstrated by von Wöhrmann[4] in the Cardita and Raibl strata of North Tyrol.

[1] My zonal collections from the Enneberg and Ampezzo Upper Trias are in the Palæontological Museum in Munich.

[2] von Wöhrmann und Koken: "Die Faunen der Raibler Schichten von Schlernplateau": Zeitschr. d. D. geol. Ges., 1892.

[3] Ogilvie: "On the Wengen and Cassian Strata in Southern Tyrol," Quart. Journ. Geol. Soc., 1893; "Coral in the Dolomites," Geol. Mag., 1894.

[4] von Wöhrmann: "Die Fauna der sogenannten Cardita u. Raibler Schichten in den Nordtiroler u. bayerischen Alpen": Jahrb. der k.k. geol. Reichs., 1889.

After the publication of my paper in 1893, at Dr. Bittner's request I sent to him in Vienna my private collection of the Falzarego Valley fauna. I hoped that in Vienna, among the South Tyrol collections of the Austrian Geological Survey, a nearer identification of the material might be attained. Thus the fauna has had the advantage of Dr. Bittner's close examination and judgment, and I am now in a position to publish a list of the types named in accordance with the most recent advances in the literature of Alpine Trias.[1] The Lamellibranchs have for the most part been described and illustrated in Dr. Bittner's "Monograph." The Roman numerals and figures entered in the list refer to that work, and the bivalves are enumerated in the order adopted there.

LIST OF FOSSILS.

Abbreviations.—C* = occurrence in Stuores-Cassian zone; R* = occurrence in Raibl zones. S.Pl. after R = occurrence also in the Raibl beds of Schlern Plateau.

	C*	R
LAMELLIBRANCHIATA.		
Cuspidaria siliqua, Bittn. (i, 19, 20)	*	...
Gonodon (Corbis) plana, Mnst., sp.	*	...
Laubeia (Megalodus) strigilata, Klipst., sp. (ii, 13–18) ...	*	...
Astartopis Richthofeni, Stur	...	* S.Pl.
Myophoriopis lineata, Mnst., sp. (xiii, 1–6)	*	* (?)
Myophoria decussata, Mnst., sp. (xii, 1–8)	*	* S.Pl.
,, *fissidentata*, von Wöhrm.	...	* S.Pl.
Myophoria (?) solitaria, Bittn. (xxiv, 27)	...	...
Trigonodus Rablensis, Gredl., sp.	...	* S.Pl.
Cucullæa (Macrodon) impressa, Mnst., sp. (xv, 1, 2)	*	* S.Pl.
Pinna, sp. inn. (v, 15, 16)	...	...
Avicula Sturi (= pars *A. Gea*, D'Orb.), Bittn. (viii, 3, 4) ...	*	* S.Pl.
,, *Cassiana* (= pars *A. Gea*, D'Orb.), Bittn. (viii, 6) ...	*	...
,, *Cortinensis* (aff. *A. Gea*, D'Orb.), Bittn. (viii, 5) ...	...	...
,, *Tofanæ*, Bittn. (viii, 9–11)	...	...
Cassianella euglypha, Lbe. (vii, 1)	*	*
,, *decussata*, Mnst., sp. (vii, 6–15, 20)	*	* S.Pl.
,, *angusta*, Bittn. (v, 23–26)	...	*
,, *Ampezzana*, Bittn. (vi, 10, 11)	...	...
Hoernesia Johannis Austriæ, Klipst. (x, 10–15)	...	* S.Pl.
Gervillia angusta, Gdf. (ix, 13)	*	*
,, *angulata*, Mnst. (ix, 11–17)	*	* (?)
,, *Ogilviæ*, Bittn.	...	...
Pecten tubulifer, Mnst. (xix, 13–15)	*	...
,, cf. *auristriatus*, Mnst. (xix, 23–26)	*	...
,, aff. *Saccoi*, Par. (xix, 22)	...	*
,, aff. *subdemissus*, Bittn. (xix, 29)	*	...
,, *Landranus*, Bittn. (xix, 21)	...	...

[1] Bittner: "Die Brachiopoden der Alpinen Trias," Abhandl. der k.k. geol. Reichsanstalt, Wien, 1890; "Die Lamellibranchiaten der Alpinen Trias," Theil i, "Revision der Lamellibranchiaten von St. Cassian," Wien, 1895. Kittl: "Die Gastropoden der Schichten von St. Cassian der Süd-Alpinen Trias," Annalen des k.k. naturhist. Hofmuseums, Wien, 1891; "Die triadischen Gastropoden der Marmolata u. verwandt. Fundstetten in den weissen Riffkalken Südtirols," Jahrb. k.k. geol. Reichs., 1894; "Die Gastropoden der Esinokalke nebst einer Revision der Gastropoden der Marmolatakalk," Annalen des k.k. naturhist. Hofmuseums, Wien, 1899. Salomon u. Böhm: "Fauna der Marmolatakalk," Palæontographica, 1895.

	C	R
Lima angulata, Mnst. (var. *opulenta*, Bittn.)	*	...
,, (*Plagiostoma*) *subpunctata*, D'Orb. (xxi, 19, 20) ...	*	...
,, (*Mysidioptera* ?) *spinigera*, Bittn. (xx, 32)	...	...
Mysidioptera aff. *vixcostata*, Stopp. (xx, 30)	...	...
,, cf. *tenella*, Bittn. (xxi, 1)	...	...
Plicatula solea, Lbe.	*	...
,, *Ogilviæ*, Bittn. (xxiii, 20, 21)	...	...
Placunopsis, sp. indet. (xxiii, 16)	...	...
Solen, *Mytilus*, *Anaplophora*, and *Myacites* (in poor specimens).		
GASTEROPODA.		
Dentalium simile, Mnst.	*	...
Acmæa (*Patella*) *campanæformis*, Klipst., sp.	*	...
Patella capulina, Braun (? *granulata*, Lbe.)	*	...
Neritopsis decussata, Mnst., sp.	*	* S.Pl.
,, *armata*, Mnst., sp.	*	* S.Pl.
Neritina imitans, Kittl	*	...
Eucycloscala (*Scalaria*) *ornata*, Mnst., sp.	*	...
Collonia cincta, Mnst., sp.	*	...
Delphinulopsis, sp indet.	...	...
Naticopsis neritacea, Mnst., sp.	*	...
,, *expansa*, Lbe., sp.	*	...
,, aff. *Cassiana*, Wissm., sp.	*	...
Ptychostoma pleurotomoides, Wissm., sp.	*	*
Ptychostoma, n.sp., aff. *Trochei*, Kittl	...	...
Hologyra Ogilviæ, Böhm	...	...
Loxonema, sp.	...	...
Goniogyra, n.sp.	...	...
Natica plicatilis, Klipst.	*	...
Spirostylus subcolumnaris, Mnst., sp.	*	...
,, *columnaris*, Mnst., sp.	*	...
Euthystylus hastile, J. Böhm (*Orthostylus* cf. *Fuchsi*, Kittl)	...	...
Hypsipleura subnodosa, Klipst., sp.	*	...
Cœlostylina crassa, Mnst., sp.	*	...
,, sp., cf. *infrastriata*, Kittl	...	...
Promathildia (*Turritella*) *subornata*, Mnst., sp.	*	...
,, sp. ?	...	...
Pseudomelania (*Turritella*) cf. *similis*, Mnst., sp.	*	*
CEPHALOPODA.		
Aulacoceras inducens, Mojs.	*	* S.Pl.
Orthoceras elegans, Mnst.	*	...
Nautilus, sp. indet.	...	...
Lobites (*Clydonites*) *nautilinus*, Mnst., sp.	*	...
Trachyceras Aon, Mnst., sp.	*	...
Pinacoceras Philopater, Lbe.	*	...
BRACHIOPODA.		
Cyrtina Buchii, Klipst., sp.	*	...
Amphiclina scitula, Bittn.	...	*
Thecospira tenuistriata, Bittn. (aff. *T. Gümbeli*)	*	* (?)
Rhynchonella cf. *tricostata*, Mnst., sp.	*	...
Terebratula, n.sp., aff. *Cassiana*, Bittn.	...	...
Waldheimia, n.sp.	...	...
ECHINODERMATA.		
Cidaris parastadifera, Schafh.	*	*
,, *dorsata*, Braun	*	* S.Pl.
,, *alata*, Ag.	*	* S.Pl.

	C	R	
Cidaris Hausmanni, Wissm.	*	*	
,, *decorata*, Mnst.	*	...	
,, *Braunii*, Desor	*	*	
,, *flexuosa*, Mnst.	*	...	
,, *Liagora*, Mnst.	*	...	
Entrochus (*Encrinus*) *Cassianus*, Lbe., sp.	*	*	S.Pl.
,, ,, *granulosus*, Mnst., sp.	*	*	
,, ,, *varians*, Mnst., sp.	*	...	
,, (*Pentacrinus*) *Tirolensis*, Lbe., sp.	*	*	
,, ,, *propinquus*, Mnst., sp.	*	*	
CŒLENTERATA.			
Cladophyllia sublævis, Mnst., sp.	*	...	
Isastræa Gümbeli, Lbe.	*	...	
Thamnastræa Zitteli, von Wöhrm.	*	...	
Toechastræa Oppeli, Volz.	*	...	
Stylina, n.sp., and several *Thecosmilia*, sp. ind.			

Reckoning the percentages from the Lamellibranchs as a sure standard, the result yields 34 per cent. new species not yet known in any of the Cassian or Raibl zones of Alpine Trias; 25 per cent. species present in the Stuores-Cassian fauna but not in Raibl horizons; 25 per cent. species common both to Stuores-Cassian and to Raibl faunas; and 16 per cent. species present in Raibl horizons but not in the Stuores-Cassian fauna. The thick-shelled larger habitus of the bivalves at once marks a difference from the Stuores-Cassian fauna, and presents a striking resemblance to the character of recognized Raibl faunas in this district, e.g. the Travernanzes Raibl fauna at the higher horizons in Falzarego Valley and the Schlern Plateau Raibl fauna farther west. This faunistic transition in the bivalves is undoubtedly attributable to renewed local accumulations of tuff and volcanic dust, to strong current action, and the frequent reconstitution of littoral molluscan colonies at one place or another as the eruptive invasions permitted. The same transition seems to have taken place simultaneously in the neighbouring localities of Rimbianco, Misurina, and Seeland Alpe (Q.J.G.S., 1893, pp. 24, 33, 36).

While the list shows clearly the close affinities of this fossiliferous zone with the older Stuores-Cassian fauna, a few observations may be made regarding the affinities with the younger Raibl fauna.

The most commonly occurring genera among the bivalves are *Avicula* and *Cassianella*. According to Dr. Bittner's terminology, two species, *A. Sturi* and *A. Cassiana*, represent the older name of *A. Gea*, while *A. Cortinensis* has close affinity with these species. On the actual ground it was *A. Sturi* which distinguished itself by the number of its representatives. On the other hand, *Avicula Tofanæ* is a more distinctive local type. *A. Sturi* occurs in North Tyrol at a high horizon of the Cardita strata, and continues in the upper (Torer) Raibl fossiliferous series. *Hoernesia Johannis Austriæ* and *Gervillia angusta* likewise continue, both in North and South

Tyrol, in the Upper Raibl zone (von Wöhrmann, loc. cit., N. Tyrol, 1889, p. 250).

Cassianella decussata and *Cucullæa impressa* are present in the Schlern Plateau strata, which von Wöhrmann regards as contemporaneous with the 'Upper Cardita' or 'Lower Raibl' series in North Tyrol.[1] Opinions differ regarding the absolute identity of the two species *Myophoria decussata* and *Myophoriopis lineata*, in the Falzarego fauna, with the types described by von Wöhrmann at Schlern Plateau, but the affinity is certainly close. *Myophoria* (?) *solitaria* has, according to Dr. Bittner, nearest resemblance to a Raibl form, *M.*, sp. *Tommasi*. The *Gervillias* and *Pectens* are genera which are relatively exceedingly rare in the Stuores-Cassian zone, but here, as in Raibl strata, they are of common occurrence and comprise a few species identical with, or closely related to, Raibl species.

Thus, the close examination which the Cortina Lamellibranchs have now undergone has served to prove that the evidence which I gave in 1893 of an Upper Cassian or Cassian-Raibl transition zone was well-founded. Previously to 1893 the only intermediate Lamellibranch fauna known in South Tyrol between the Stuores-Cassian zone and the typical Torer Raibl zone was the Schlern Plateau fauna, but a palæontological gap existed between it and the Stuores-Cassian zone.

With regard to the Gastropods in the foregoing list of the Upper Cassian fossils in Falzarego Valley, the majority of the species are identical with Cassian species. This is natural, since the Stuores-Cassian fauna is characterized by the extraordinary number of small Gastropod species and individuals, whereas the Raibl fauna is characterized by a greater number of Lamellibranchs in proportion to the number of Gastropod species. As a local feature it may be noted that certain species, e.g. *Neritina imitans* and *Scalaria ornata*, are present in relatively far greater number of individuals in the Falzarego area than in the Stuores Meadowland. More important as a sign of transition is the occurrence in large number of individuals of two species, *Neritopsis decussata* and *armata*, which are common both to the Stuores-Cassian zone (in small number) and to the Schlern Plateau and other Raibl faunas. *Ptychostoma pleurotomoides*[2] is a species numerously represented in the Upper Cassian zone in Falzarego Valley and at Heilig-Kreuz, and is one which continues in Raibl horizons.

Another interesting feature in connection with the Gastropods is, that several species are identical with species found in the Marmolata-Kalk or calcareo-dolomitic facies south of this area, and that the beds of dolomitic limestone which immediately overlie the Falzarego tuffs are locally full of Gastropod fossils. The transitional Cassian-Raibl relations of the other groups call for less remark. Amongst the Brachiopods, *Amphiclina scitula*, amongst

[1] von Wöhrmann, "Die Raibler Schichten," m. Uebersichtstabelle: Jahrb. k.k. Reichs., 1893, p. 768.

[2] See Kittl, "Die Gastropoden der Schichten von St. Cassian der Süd-Alpinen Trias": loc. cit., pp. 157–8.

the Echinoderms, *Pentacrinus Tirolensis* and *Cidaris parastadifera*, continue in the highest Raibl horizons. In all groups the revised list is found to fulfil the requirements of a palæontological bridge between the Stuores-Cassian and the Schlern Plateau (or Upper Cardita) strata, and therefore to merit the place I assigned to the fauna in the percentage table and accompanying remarks of my earlier paper (Q.J.G.S., 1893, p. 44; also GEOL. MAG., 1894, p. 10 seq.).

I now submit the complete series of Upper Triassic zones in Falzarego Valley.

PALÆONTOLOGICAL AND STRATIGRAPHICAL SERIES.

	Locality: Schlern. Comparative extract from von Wöhrmann's "Die Raibler Schichten": Uebersichtstabelle, 1893.	Locality: Falzarego Valley and Travenanzes. (Cf. Ogilvie, 1893–4.)
Upper Raibl Series.	Horizon *d* (von Wöhr.). Dolomite banks with species of *Megalodus*. Dolomite with coral growths, etc.	Dolomite bands and variegated marls. Numerous *Megalodus* fossils: *Megalodus triqueter*; *Megalodus* cf. *compressus*. Thin band of dolomite weathered as terrace. '*Ostræa* marls' and limestones: leading type, *Ostræa montis caprilis*. Thick-bedded limestones, full of imperfect Pecten fossils: *Pecten Hallensis*, etc. 'Cipit Limestone' bed with coral and echinoderm remains. Soft, flaky limestone, with ammonite and nautiloid sp. Gypsum, red marls, dolomitic flagstones, rauchwackes. Hard arenaceous limestones, poor in fossils.
Lower Raibl Series.	Horizon *e* (von Wöhr.). Red Schlern Plateau fossiliferous strata with *Myophoria fissidentata* and *Kefersteinii*, *Pachycardia Haueri*, *Trigonodus Rablensis*, *Hoernesia Johannis Austriæ*, *Patella J. Boehmi*, *Tretospira multistriata*, *Joannites cymbiformis*, etc. (Sphærocodien, coral growths, plants, etc.) Horizon *b* (von Wöhr.). Stratified dolomite.	Brown sandstones, the chief horizon of *Myophoria Kefersteinii* & *M. Whateleyæ*; *Myophoria fissidentata*, *Myophoricardium lineatum*, *Physocardia Ogilviæ*, *Trigonodus Rablensis*, *Hoernesia Johannis Austriæ*; *Pecten*, sp.; *Turbo*, n.sp.; plant stems; numerous coaly fragments, and specks of various mineral ores; 'Cipit Limestones' interbedded with sandstones. Thin band of dolomite weathered as terrace. Red nodular marls of tufaceous character. Quartziferous sandstones with *Trigonodus Rablensis*, *Myophoria fissidentata*, etc., passing into upper horizons of Cliff of stratified dolomite, and finely interlayered volcanic sand; locally developed as dolomitic limestone, with many Gastropods; in lower horizons interbedded with

Lower Raibl Series (= Cardita Strata, North Tyrol).	Horizon *a* (von Wöhr.). Augite porphyry and tuffs.	Upper Cassian Series.	'Cipit Limestones' and volcanic tuffs; tufaceous marls, impure limestones, lignite, and aragonite. *Spirostylus subcolumnaris, Ptychostoma pleurotomoides, Neritopsis decussata, armata, Astartopis Richthofeni*, and crowded fragments of species of *Solen, Plicatula, Placunopsis, Avicula*, etc.
			Pale-greenish tufaceous shales, reddish-brown tufaceous breccias with quartz grains, glassy and metalliferous ore inclusions, limestones with uneven bedding surfaces. These are the chief horizons of Upper Cassian bivalves: *Avicula Cortinensis, Tofanæ, Sturi, Cassiana*; *Cassianella decussata*; *Gervillia Ogilviæ, angulata*; *Myophoria decussata*; *Hoernesia Johannis Austriæ*; *Lima angulata*; *Pecten Landranus, tubulifer*; *Trigonodus Rablensis*; etc.
		Lower or Stuores-Cassian Series.	Irregular crags and blocks of 'Cipit Limestones' in tuffs.
			Dark tufaceous earth and marls; thin-bedded shales and limestones containing rich fauna of small forms, in typical 'Stuores' character: *Cardita crenata, Koninckina Leonhardti, Trachyceras Aon, Nucula lineata, strigilata, Schizogonium subcostatum*, etc.
			Gypsiferous marls, aragonite, tufaceous grits and shales with 'Cipit Limestones'; sponges, corals, echinoderms, *Posidonomya Wengensis*, etc.
		Wengen Series.	Ashy and felsitic series, black tufaceous earth, occasional dark bituminous limestones: *Halobia Lommeli, Posidonomya Wengensis*, plants, etc. (for Stuores-Cassian and Wengen Series, cf. aut., 1893, p. 16).

The Lower and Middle Cassian horizons, distinguished by me in 1893, are here combined as one palæontological zone, the Lower or Stuores-Cassian zone; since, although the subdivision is useful in field survey, the horizons are not palæontologically independent.

The stratigraphy of the Upper Cassian zone in Enneberg and Ampezzo is more difficult than the palæontology, since the lower Raibl fossiliferous sandstones are replaced by various local facies, wholly dolomitic (as at Lagazuoi), or developed as a series of dolomitic limestones and irregular banks of dolomite, interbedded with marls and sandstones (as at Roces Alpe).

In Falzarego Valley the Upper Cassian tufaceous series rests conformably upon Cassian strata containing the typical Stuores fauna, and is succeeded by a bed of dolomite of varying thickness, in some places fossiliferous, with Gastropod colonies, coral banks, algæ, etc., in others unfossiliferous and interlayered with volcanic sand

and nodular iron ore. Sometimes the sandy material occurs in patches, sometimes in layers a few inches thick, sometimes in layers as fine as the finest dust. The chemical decomposition of the calcareous and the volcanic material and the weathering-out of the finely and coarsely interlayered sands and tuffs from the rock largely account for the frequent occurrence of toothed and fantastic erosion forms at this horizon of the Schlern Dolomite.

The relations of these dolomitic and sandy layers are such as are presented to us in recent descriptions of volcanic and organic muds in the vicinity of oceanic islands, or more generally of 'Red Clay' and pelagic 'Oozes.' I have always held that the deposits of Raibl age represented the actual sediments in South Tyrol in which a dolomitic character may be regarded as original ("Coral in the Dolomites," 1894, pp. 11–13, 20–22), and that it was there associated with chemical decomposition going on contemporaneously with sedimentation. My specimens from this horizon are under examination in Prof. Armstrong's laboratory at South Kensington.

The chemist is confronted in the dolomites with the same possibilities of chemical decomposition and interchange, both in the past submarine and in the present subaerial conditions, which were clearly set forth by Sir John Murray in his Presidential Address to the Geographical Section, British Association, 1899, from which I quote the following passages: "The inorganic constituents of the Pelagic Deposits are for the most part derived from the attrition of floating pumice, from the disintegration of water-logged pumice, from showers of volcanic ashes, and from the débris ejected from submarine volcanoes, together with the products of their decomposition. . . . . If the whole of the carbonate of lime shells be removed by dilute acid from a typical sample of Globigerina Ooze, the inorganic residue left behind is quite similar in composition to a typical Red Clay. . . . . The volcanic materials in a Red Clay having, because of the slow accumulation, been for a long time exposed to the action of sea-water, have been profoundly altered. The massive manganese-iron nodules and zeolitic crystals present in the deposit are secondary products arising from the decomposition of these volcanic materials."

The development of organic and inorganic muds, with all possible variations in the alternative bedding, is the normal character of the Schlern Dolomite within Enneberg and Ampezzo. And, as I previously pointed out, the contemporaneity of this dolomitic series, in whole or in part, "*with fossiliferous Raibl strata elsewhere* (e.g. *the Schlern Plateau strata*) *would in nowise afford evidence of the Coral Reef Theory, but only of the familiar fact of Raibl heteropism.*" ("Coral in the Dolomites," 1894, p. 13.)

The dolomite cliff and marls in Falzarego Valley, Roces Alpe, and Travenanzes are succeeded by a well-defined group of sandstones, shales, and shaly limestones, in which a typical Raibl fauna occurs. The fossils enumerated at this horizon, in the above table of Upper Trias, were all personally collected from a number of places along this high mountain terrace above the valley. Strange

to say, I never found *Pachycardia Haueri*, which is such a numerously represented type in the Schlern Plateau strata. The limited colonial aspect of local faunas seems to have been the leading palæontological feature of the Cassian-Raibl period.

Whilst the age of the intervening calcareo-dolomitic and sandy series is quite securely fixed by the presence of the *Myophoria* and *Ostræa* fossil zones above, and the *Avicula Tofanæ* and *Cortinensis* fossil zones below, I have always referred to it in previous papers as "Schlern Dolomite," following the original intention of von Richthofen, who applied this term to any dolomitic facies of Upper Triassic tufaceous series in the district. The fossiliferous Upper Cassian tuffs are present at Pec di Palu, south of the Falzarego road, and may be followed over Valparola, Pordsi, and Sella Pass to the south of Langkofl and Mahlknecht. Remnants of the series occur at Cra di Mont, Crap di Sella, Freina Meadow, and elsewhere farther north.

I already showed, in 1893–4, that throughout Enneberg and Ampezzo the *horizons of Raibl time were those which displayed the most extreme and complex facies relations.* All Raibl zones pass now at one place, now at another, into local massive developments of Schlern Dolomite (e.g. Lagazuoi, Dürrenstein, etc.). The Upper Cassian zone also presents varying local facies relations *within* Enneberg and Ampezzo, but the Wengen and Stuores-Cassian zones underlie the dolomitic deposits in Enneberg and in all parts of Ampezzo which I have examined. Thus, the identification of successive palæontological zones proves that the tufaceous invasions overspread the floor of the Enneberg and Ampezzo areas more generally in the earlier periods of the Upper Trias epoch in South Tyrol. And the passage-limit between the tufaceous material and the ordinary sediments was at that time locally situated within that wide 'Buchenstein-Mahlknecht' series of lavas and tuffs which represents one of the chief local areas of contemporaneous eruptive fracture-planes. These are the heteropic conditions which I have depicted in a series of diagrams, showing the successive stages in the accumulation of deposits, and the intermixture from time to time of volcanic material during the Wengen, Cassian, and Raibl periods ("Coral in the Dolomites," 1894, Geol. Mag., Pl. II).

In the second part of the same paper (in the Geol. Mag.), Sasso Pitschi (a small mountain that occurs in the Buchenstein-Mahlknecht passage-area of facies) was selected as an example of the tendency displayed by later differential movements to coincide with the original passage-areas between different lithological groups of strata, whether these areas occurred in the horizontal extension of different rock facies, as at Sasso Pitschi, or in the ordinary geological succession. My publication[1] in 1899 rests on the same standpoint.

[1] "Torsion-Structure of the Dolomites": Quart. Journ. Geol. Soc., 1899. Attention may be directed here to a printer's slip that unfortunately evaded me in the proofs, and which causes some confusion: see p. 580, under '5,' near the bottom of the page: "A and C to be moved counterclockwise, B and D clockwise," should read "A and C to be moved clockwise, B and D counterclockwise."

Subordinate movements have readily taken place at the planes where the more rigid and the more plastic rock-groups have been next one another. Thus local conditions have produced local modification of the more general movements due to compression and cross-compression of this district in subsequent epochs of Alpine upheaval.

In addition to its use in the solution of the stratigraphy, the value of an Upper Cassian fauna is in the link it adds to the Upper Trias chain of faunas in South Tyrol. Its discovery and its identification by me in 1893 as a transitional Cassian-Raibl zone established, for the first time in South Tyrol, a closely connected series of palæontological zones traceable through Wengen-Cassian-Raibl periods. The Upper Cassian zone has therefore given important evidence of the impracticability of placing a palæontological limit between Middle and Upper Alpine Trias anywhere within that series. The transition from Raibl horizons to Dachstein Dolomite in Enneberg and Ampezzo also takes place quite gradually, as evidenced by species of the genus *Megalodus*. Hence the only subdivision between Middle and Upper Trias which seems natural in the 'Dolomites' is between the Upper Muschelkalk (Buchenstein strata of some authors) and the Wengen series, that is, at the horizon of Triassic time, when eruptive material began to be incorporated with the local sediments of that area. (Cf. von Wöhrmann, "Die Raibler Schichten," 1893; Rothpletz, "Querschnitt," 1894; Salomon, "Palæontographica," 1895; von Zittel, "Zeitschrift," 1899.)

A farther confirmation of the presence of a transitional Cassian-Raibl fauna in the 'Dolomites' has been given by the fauna in the '*Pachycardia* Tuffs' of the Seiser-Alpe. Geheimrath von Zittel, who made the discovery, during a geological excursion with his students, that these tuffs contained a large number of Raibl forms in addition to Cassian forms, has since published a short account of the faunal characteristics of these tufaceous horizons at the Seiser-Alpe (von Zittel, "Zeitschrift," 1899; also Rothpletz, "Zeitschrift," 1899). The preliminary notes on the stratigraphy given by Prof. Rothpletz show that these tuffs at the Seiser Alpe rest conformably upon strata containing a Stuores-Cassian fauna, so that in this important feature their position at the Seiser-Alpe agrees with that which I determined at Falzarego Valley and other localities. The 'Cipit Limestones' also occur, as blocks or irregular banks, at various horizons, in the way that I described for other localities along the Buchenstein-Mahlknecht area of eruptive invasions. "Along the hem of this volcanic girdle communities of Corals and Echinoderms settled and formed a series of small barrier reefs (Cipit Limestones), frequently interrupted in their growth by fresh lavas" (aut., l.c., 1894).

But, compared with the Falzarego Valley fauna, the '*Pachycardia*-tuff' fauna bears a distinct local impress. For example, just as I never found *Pachycardia Haueri* in the higher Raibl horizons of Falzarego Valley, so I never found *Pachycardia rugosa*, the leading fossil of the *Pachycardia* tuffs, in the Upper Cassian zone of Falzarego Valley. Both may be there, as my personal collection

can only represent a small part of the fauna, but they at least cannot be common.

A similar impression of narrow spacial limitation is given by each of the local developments of a fossiliferous Upper Cassian zone, at Heilig Kreuz, Seeland Alpe, Misurina, and Rimbianco. This horizon of Upper Triassic time is characterized, therefore, not only by marked differences in the local lithological facies, but also by marked local specializations in the aspect of contemporaneous faunas inhabiting neighbouring seas and lagoons. Many of the fossils have affinity with Cassian or Raibl species, yet can neither be identified with, nor clearly distinguished from these. Hence, we may regard it as probable that those specialized Upper Cassian faunas included, amongst the species peculiar to themselves, certain types due to strong adaptation or to retrogression. And we may learn from the faunas of the Upper Cassian zone, no less than from those of the higher Raibl zones, that there are biological questions in South Tyrol which concern the occurrence of pelagic and of littoral faunas as local colonies in a neighbourhood of very unequal depth and subject to volcanic interruptions in the form of lavas, tuffs, and fine volcanic sand. These questions are one with the consideration of lithological facies in the same district.

The following table of Upper Trias strata in South Tyrol represents the zonal succession and local occurrence of facies as described in former papers (cf. Geol. Mag., 1894, Pl. II, and Q.J.G.S., 1893, p. 16).

	Fassa-Schlern, south of the Buchenstein-Mahlknecht eruptive fractures.	*Within* Enneberg and Ampezzo, north of the Buchenstein-Mahlknecht eruptive fractures.
Upper Trias (South Tyrol).	Dachstein Dolomite.	
	Raibl series.	or Upper Raibl series (von Wöhrmann), with *Ostræa* and *Megalodus* beds.
	Schlern Dolomite.	Schlern Dolomite: or Lower Raibl series (von Wöhrmann), equivalent to Upper Cardita series in North Tyrol, represented by "red Schlern Plateau fossiliferous series" or by a varying thickness of stratified dolomite in South Tyrol.
		or Upper Cassian tufaceous series (Ogilvie), with *Avicula* beds.
		Cassian series in 'Stuores' development.
		Wengen series, with *Halobia Lommeli*.
	Upper Zone of Muschelkalk or Middle Trias.	

As, however, Baron von Wöhrmann, in his comparative work on "The Raibl Strata," found the palæontological transition quite gradual throughout the Cardita and Raibl zones in South Tyrol, he included the whole series from the *Halobia Lommeli* to the *Ostræa* beds as Raibl strata in wider sense (cf. "Uebersichtstabelle d.

Raibler Schichten": Jahrb., 1893). Hence, to continue to call the 'Red Schlern Plateau' series 'Lower Raibl' would undoubtedly cause confusion. The distinction of Upper, Middle, and Lower Zones in a series of 'Raibl strata' (using the term in the now wider sense given by von Wöhrmann), might be locally possible, but at the present time it is more important to arrive at a clear presentation of the complete series of palæontological zones in each Alpine locality. Thus in South Tyrol we have:

LEADING FOSSIL-TYPES

in the Wengen-Cassian-Raibl series ('Raibler-Sch.' in wider sense, von Wöhrmann).

	'Torer'-Raibl Zone: *Ostræa montis caprilis, Megalodus triqueter*, etc. (diverse local developments of volcanic marls and sand, limestone, gypsum, dolomite).
	'Red Schlern Plateau' Raibl Zone: *Pachycardia Haueri, Myophoria Kefersteinii, Myophoricardium lineatum*, etc. (diverse local developments of volcanic sand and calcareo-dolomitic facies; molluscan faunas contain almost exclusively Raibl species).
All pass into the Calcareo-dolomitic facies in South Tyrol; von Richthofen's 'Schlern Dolomite.'	Upper Cassian or Transitional Tuff Zone: *Avicula Sturi, Tofanæ*, and *Cortinensis, Pecten Landranus*, etc. (diverse local facies of Upper Cassian series, containing a mixed fauna of Cassian and Raibl species).
	Stuores-Cassian Zone: *Koninckina Leonhardti, Cardita crenata, Nucula strigilata* (tufaceous, marly, and calcareous series, containing almost exclusively Cassian species).
	Wengen Zone: *Halobia Lommeli, Monophyllites Wengensis, Trachyceras Archelaus, Posidonomya Wengensis*, etc.; series of shales and limestones, grits, tuffs, and lavas.

Summary.

(1) Conformably above strata containing the typical or Stuores-Cassian fauna as known before my paper of 1893, and below any palæontologically well-defined Raibl horizon, so regarded before von Wöhrmann's paper of 1893, I found in Falzarego Valley in 1891 a series of tufaceous breccias, shales, and quartziferous sandstones, containing a transitional Cassian-Raibl fauna, and passing upward into interstratified dolomite, dolomitic limestone, and volcanic sand and marl, or into a wholly dolomitic group of strata. The latter I termed 'Schlern Dolomite,' stating it to be the time-equivalent in part, or wholly, of the 'red Schlern Plateau fossiliferous strata' which von Wöhrmann had in 1892 called a Lower Raibl zone in South Tyrol. Revised identifications of my Falzarego Valley material, carried out in accordance with the recent special monographs on Alpine Molluscan faunas by Dr. Bittner, Dr. Kittl, Dr. J. Böhm, and others, have fully corroborated the palæontological position which I gave to the fauna in 1893–4 as a local 'tuff' facies

of part of the Schlern Dolomite, comprising a gradual transition from a typical Stuores-Cassian fauna to the 'Travenanzes' Raibl fauna of the Falzarego district.

(2) The Wengen and Stuores-Cassian fossiliferous tufaceous series are present throughout the district of Enneberg and Ampezzo in complete zonal development. These palæontological zones are therefore *not*, as has been said, the tufaceous facies of the dolomitic rock composing the massives in these areas. On the other hand, the Upper Cassian zone and the higher Raibl zones are developed in varying degree *within* Enneberg and Ampezzo as local facies of local dolomitic sediments. 'Cipit Limestones' (the true coral-reefs of the district) occur both in the tufaceous and in the dolomitic facies at all horizons as occasional local beds of comparatively small thickness (loc. cit., Geol. Mag., 1894).

(3) The Wengen and Stuores-Cassian tufaceous and calcareous series of Enneberg and Ampezzo represent time-equivalents of part of the calcareo-dolomitic series south of the Buchenstein-Mahlknecht passage-area of facies, that area having been one of the chief localities of contemporaneous eruptive fracture-planes.

(4) In many cases the passage-areas between facies of different lithological character, as well as the passage-bands between subjacent rock-groups of different lithological character, have been the seat of subsequent differential movement or distortion. So that the complex local developments of passage-areas and passage-bands in the Upper Trias of South Tyrol have induced many local effects of cross-movement which now complicate the stratigraphy of that district.

(5) The more general movements associated with Cretaceous-Tertiary upheaval in the Eastern Alps have called forth an east-west strike, which must be regarded as fundamental in the district, and also a cross-compression from east and west or slightly oblique directions. The complex resultant system of folds, faults, and overthrusts has been cut by subsequent faults associated with local subsidences.

II.—The Geology of Bad Nauheim and its Thermal Salt-Springs.

By A. Vaughan Jennings, F.L.S., F.G.S.

I. Introduction.
II. General Physiography.
III. The Rock-Formations present.
IV. The Springs, Borings, and 'Salines.'
V. The Geological Problems involved.

I. Introduction.

THE eastern extremity of the wooded range of the Taunus, where its last spurs slope down to the Wetterau Plain and the streams from its valleys give up hurrying and wander lazily across the fertile flats towards the Main, has been a spot rich in interest since at least pre-Germanic times. The ancient Kelts, when

overwhelmed by their Germanic foes, left behind them, now deep in the detritus at the foot of the Johannisberg, their hearths, chisels, and millstones, mixed up with shells and bones. In addition to these typical relics of the race, there have also been found special forms of earthen vessels, used evidently for evaporating the waters of the saline springs. The tribes described by Tacitus as being in possession at the end of the first century do not seem to have been similarly enterprising, but it is known the victorious Romans of the third century resorted thither for medicinal baths.

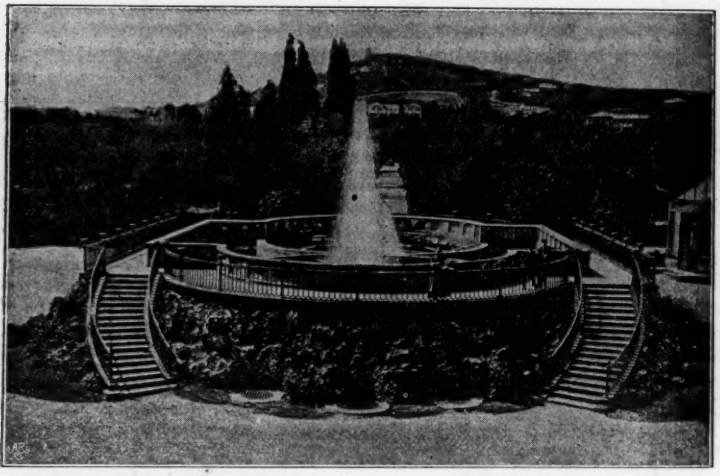


Fig. 1.—Bad Nauheim. View looking west. In the foreground the Grosser Sprudel and Friedrich-Wilhelm's Quelle [Borings 7 and 12]. The Johannisberg in the distance.

The place was, in fact, a Roman sanatorium sixteen centuries before the modern Teuton evolved the 'Kur' to music, or the somewhat over-subtle phonendoscope whispered in the doctor's ear of fell diseases that are at work below, and perhaps, occasionally, of some that are not. In mediæval times and throughout the later centuries its ancient reputation was sustained and increased. The nineteenth has seen the opening of a system of baths in 1835, which has so advanced in public estimation that the number of visitors has risen in 60 years from 189 to 17,760, and of baths from some 112,000 in 1890 to over 227,000 in 1897.

It is not, however, the object of this paper to give statistics or to advertise a health resort. The above figures are quoted only to indicate the growth of the place as a justification for giving some account of its geological features in English. Several thousands of the visitors annually are British, and I have found that there really is a small percentage, even of these, who would be glad to know something of the structure of the country which produces the waters they seek to benefit by.

It is a matter of great difficulty to obtain information on the spot, as the geological map and its description are old and out of print; while the excellent guide, written in 1888 by Herr Bergrath Otto Weiss[1] and Dr. Groedel, contains in its geological chapter some views as to the order of succession of strata which later research has corrected, and is insufficiently illustrated to give a clear idea of structural features. This is my excuse for attempting to give some sort of account of the district, though an imperfect one. For many of the details I am of course indebted to the older works mentioned at the end, but on the other hand a considerable part of the following notes are from personal observation, though made only on short excursions under conditions of a necessarily limited activity.

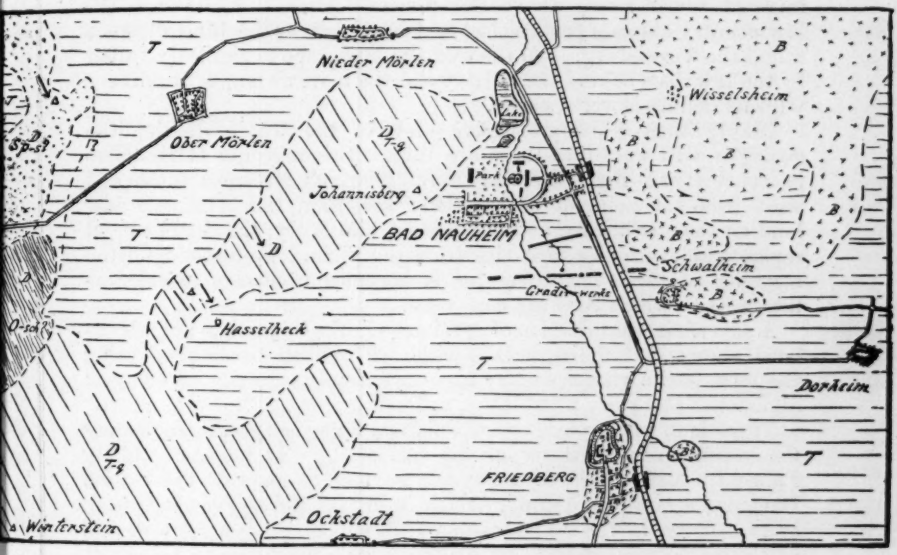


Fig. 2.—Geological Sketch-map of country around Bad Nauheim.

B. Blättersandstein. O. Orthoceras-schiefer.
D. Devonian series. Sp. Spiriferen-sandstein.
T. Taunus-quarzit.

II. General Physiography.

The old village of Bad Nauheim, and the new town which has grown up beside it round the springs, lie at the foot of the Johannisberg. The hill, rising 858 feet above the sea and about 390 feet above the plain, is wooded at the top and on the northern slopes;

[1] Herr Weiss has been identified with the history of the locality from the earliest days of organized baths, and knows more than anyone else as to the various borings. He was most courteously willing to give all information, but unfortunately his illness prevented my profiting by his store of knowledge, except in a few minutes interview when I was on the point of leaving.

vine-clad on its steeper southern aspect, but scarred here and there by reddish rock patches where the iron-stained quartzites of which it consists have been quarried for building material or for road-metal. From the summit there is a drop on the south and west to the saddle at Hasselheck, and then a steady rise to the Winterstein and the general mass of the Taunus. Towards other points of the compass one looks over a wide valley-country with rich fields and scattered villages and trees, so that our hill of observation constitutes as it were a promontory running out from the high ground into the plain.

On the south the plain stretches away twenty miles to Frankfurt, merging into the broad valley of the Main. The plain is not, however, a monotonous level, as in the foreground rises the low hill on which stands the old town of Friedberg, with its picturesque turreted tower rising above the ancient fortress. Northward the low country extends past Weisel and Butzbach to the blue distance round the Vogelsberg. To the east the landscape is similarly varied by the low rises behind the railway and the more distant Münzenberg with its double-towered castle.

Taking thus a comprehensive view of the whole district, the geologist will note that there are three distinct scenic elements to be considered. First, the Taunus range which stretches south and west from his point of observation; secondly, the relatively low land on the south, east, and north-east; and lastly, the detached and separated elevations which rise from the plain. To understand the meaning of these three features it becomes necessary to examine the rocks of which they are composed.

A superficial examination of specimens in the immediate neighbourhood shows that the rock is a white or reddish 'quartzite,' using the term in its widest sense; more accurately, a series of compact sandstones and grits which have suffered greater or less alteration.

There is in many places a well-defined flaggy structure, indicating the sedimentary character of the formation. It has a distinctly Palæozoic aspect, and in many places recalls some of the British Devonian strata to the mind. Such is, in fact, the age ascribed to it, as it belongs to the 'Taunus-quarzit,' which, though here devoid of fossils, is now known, by observations elsewhere, to belong to the Lower Devonian series.[1]

The dip of the beds is here a very steep one to the south and east, but many variations will be found in the districts lying to the west. In fact, the whole range is much contorted and the strata doubled up in sharp folds, as has been shown by Koch, Kayser, and others.

Leaving for future consideration the question of the presence of other strata than the 'quartzite' in this Palæozoic ridge, and descending to the lower ground, one meets with a marked change in the character of the rocks, though the wooded condition of the ground and the accumulation of detritus and Post-Tertiary deposits have to a great extent obliterated the abruptness of the transition.

[1] The suggestion of Gosselet (Ann. Soc. Geol. Nord, xvii, p. 300) that the base of the series is Archæan does not seem to be accepted by English or Continental geologists.

In the quarries south of Bad Nauheim or round the village of Ockstadt there is a series of sands, sandstones, pebble-beds, and loosely cemented conglomerates, which are horizontally stratified and evidently of far later date than the rocks of the hill. They are, in fact, Tertiary beds representing the infilling of a great lake which once occupied the whole of the western district.

If one crosses the broad zone of fertile fields covering these later strata, the hill at Friedberg shows another abrupt change. Here, though the outer slopes of the hill are green and gradual, there are rough black crags under the castle of distinctly basaltic appearance. Round Schwalheim and Wisselsheim there are less prominent exposures, but it is easy to ascertain that these eastern elevations are of the same lithological nature.

III. The Rock-Formations present.

It is therefore evident that the three scenic features above referred to have a definite geological meaning, and that the component parts of the whole area may be classed under three corresponding headings—

A. The Palæozoic Ridge.
B. The Tertiary Strata.
C. The Igneous (basaltic) Series.[1]

Before proceeding to a study of the position of the salt springs and borings it will be well to notice in somewhat greater detail the characteristics of these different formations.

A. *The Palæozic Ridge.*

As has been already observed, the Palæozoic rocks are of Devonian age; a series of flaggy, more or less ferruginous, altered sandstones, grits, and 'quartzite.' They are evidently of sedimentary origin and belong to the 'Taunus-quarzit' group; overlying the 'Sericit-schiefer,' but stratigraphically below the other members of the Devonian system. Fossils are apparently absent, though some obscure plant remains are said to have been found near the Winterstein. The strike is N.E.–S.W., and the dip varies from 28° S.E. to 72° or more in the same direction. It is not probable that the student will meet with any other form of Palæozoic rock in the neighbourhood, but if he has an opportunity of consulting the geological map he will find certain other formations recorded. Thus the 'Stringocephalen-kalk' is mapped as occurring near Hasselheck. I have been unable to find it there, and in suggesting a doubt as to its presence I am glad to find I have the support of Professor Wittich. The 'Orthoceras-schiefer' are similarly marked as cropping out by the Teich and north of Nieder Mörlen, but I have not been able to identify them in either locality. The

[1] Throughout this paper the Post-Miocene deposits are left out of consideration. There is doubtless much interesting matter awaiting study in this direction, and Herr Professor E. Wittich (see list of references at end) has studied what he regards as Pliocene and Glacial beds in the neighbourhood.

'Spiriferen-sandstein' is recorded from the borings, but has not been mapped as appearing at the surface in the immediate neighbourhood.[1] In the concluding section of this paper the relationship of these formations will be again referred to, and a possible explanation of their position in the borings suggested. Even if, however, there have been errors of observation in the field, it is probable that the evidence of the borings may be trusted in showing the existence of these formations below the surface. Comparison with other districts would lead one to expect them here, as the usual succession for North Germany is as follows:—

(A) Upper Devonian { Cypridinen-schiefer / Goniatiten-kalk } Absent.

[1] (B) Middle Devonian { Stringocephalen-kalk. / Calc-schiefer = 'Orthoceras-schiefer.'

[2] (C) Lower Devonian { Koblenzer Grauwacken / Hunrückschiefer } = 'Spiriferen-sandstein.' / Taunus-quarzit. / Taunus-phyllite = 'Sericit-schiefer.'

B. *The Tertiary Strata.*

The softer, almost horizontally stratified, beds which form the fertile fields of the Wetterau belong, as already stated, to Oligocene times. In the south-west the whole series of strata is well seen, but at Bad Nauheim itself it is only the upper part that is represented at the surface. In the quarries south of the town and round Ockstadt this portion, however, is typically developed and easily observed. In places there are loosely compacted sands, beautifully colour-banded, and reminding one of those at Alum Bay. Other beds consist of coarse quartz-sand with some ferruginous cement, but infiltrated with calcite, the shining cleavage faces of which often extend over considerable areas. Selenite and chalybite are also commonly present. In the coarser beds the pebbles of older rocks are frequently coated with concentric pellicles of yellow, brown, or brilliantly red iron oxides, and a remarkable ferruginous conglomerate results.

In spite of their varied character these strata appear to belong all to the 'Blättersandstein.' Though unfossiliferous here, they contain at Münzenberg such mollusca as *Litorinella*, *Cyrena*, *Unio*, *Cyclas*, and *Helix*, as well as leaves of plants such as *Cassia*, *Rosa*, *Acer*, *Ficus*, *Cinnamomum*, *Sapindus*, *Amygdalus*, and *Cratægus*.

Below the Blättersandstein comes the 'Litorinellen-kalk,' a yellowish limestone with fossils; again partly of fresh and partly of brackish water habit. *Succinea*, *Pupa*, *Helix*, and *Neritina* occur

[1] The nearest is a little west of Ober Mörlen, where it is said to occur with a dip of 40°–50° S.E. in the same strike line as the Oppershofen-Krausberg outcrop, where characteristic fossils occur. A patch of schiefer, believed to be equivalent to those of Pfaffenwiesbach containing *Orthoceras*, is mapped as occurring immediately south of the sandstone.

[2] All these strata are unfossiliferous at Bad Nauheim, but in the Koblenz district contain characteristic types, such as *Rensseleria*, *Meganteris*, *Pentamerus*, and *Ctenocrinus*. In other parts there occur *Stromatopora*, *Calamopora*, *Fenestella*, and *Chonetes sarcinulata*.

together with *Cyrena* and *Mytilus*. A specially interesting feature is the occurrence at Bönstadt of porous limestones, evidently formed by incrustation of Algæ such as *Vaucheria* and *Chara*, with shells bearing a fibrous overgrowth, apparently due to incrustation of *Chætophora*.

Under this lies the 'Cerithienkalk,' with *Nerita*, *Mytilus*, and *Litorina* in association with familiar friends of the Hampshire Basin, such as *Cerithium plicatum*, Lam., and *Cytherea incrassata*, Sow.; passing gradually below into the 'Cerithiensand and Sandstein.' In this case also there are beds with typical land or freshwater shells—*Helix*, *Bulimus*, *Pupa*, and *Planorbis*—but these occur in narrow and unimportant bands, while the associated strata contain not only the brackish-water genera but also such marine forms as *Perna*, *Fusus*, and *Bulla*.

At the base of the series lies the 'Cyrenenmergel,' a blue or yellow, clayey or sandy deposit, in which the proportion of marine shells is still greater, and includes, in addition to those above mentioned, *Nucula*, *Buccinum*, and *Murex*.

C. *The Igneous Series.*

The hills formed by the third group of rocks in the Nauheim neighbourhood have been spoken of as interrupting the continuity of the Tertiary plain, but they do not rise with the striking abruptness of, for instance, the phonolitic Hohentwiel and neighbouring basaltic hills in Southern Baden. They are low, rounded elevations, except at the north end of the Friedberg outcrop, evidently parts of lava flows rather than denuded volcanic necks.

The rock itself appears to be a typical dark basalt; often compact and without crystals distinguishable by the eye, but at times with distinct clear green olivines. It is rarely slightly vesicular,[1] but shows a slight tendency to columnar jointing in places. Weathering results in the usual pale-brown crust, and often a rough spheroidal structure is revealed in the process.

Surface accumulations seem everywhere to mask its actual contact with the Tertiary beds, but I have been unable to observe any phenomena of metamorphism in the latter. This at first sight gives one the impression that the basalts are older than the Oligocene strata, but there is evidence elsewhere to show that such is not the case. At Wickstadt, for example, the Litorinellen-kalk is overlaid by basalt.

IV. The Springs, Borings, and 'Salines.'

Having thus obtained some insight into the nature of the strata of the district, one is led to consider what is the relationship between the character of these rocks and the presence of the thermal and saline springs to which the locality owes its fame. With this in view it will be necessary to note in some detail the position and

[1] There is a brownish-grey scoriaceous rock, which is used in Nauheim for kerbstones, etc., but which I could not find *in situ*. Closer observation showed the presence in it of clear blue Hauyn crystals, and it probably comes from the well-known quarries of Niedermendig.

depths of the various borings and some of their characteristic phenomena. As, however, a good deal of statistical information is obtainable from the guidebooks published on the spot, an attempt is here made to direct attention only to such facts as bear on the geological questions involved.

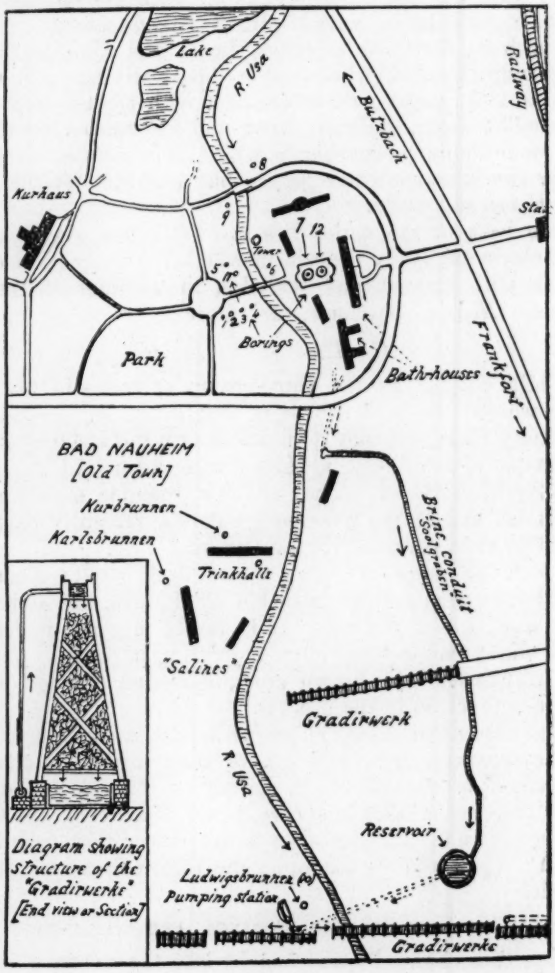


FIG. 3.—Ground-plan of Bad Nauheim showing site of Old Town and New Baths and Park, with Springs and Borings.

The various borings which have been made during the present century in order to obtain a larger supply than that yielded by the small natural springs, have been numbered from 1 to 12.

That known as No. 1 (ignoring an attempt made in 1816) was made in 1823; it was carried down 18 metres, and gave a spring

yielding 284,500 litres a day, with 2½ per cent. of salt and a temperature of 25° R. The second, made in 1824, was 153 metres in depth; it gave water of similar composition at 21° R. Nos. 3 and 4 were stopped at 31 and 22 metres respectively.

These four[1] were bored near together in a N.E.–S.W. line on the south-east side of the circular 'platz' which now occupies the centre of the park. No. 5 seems to have been a little north-west of these, and was undertaken in 1838. At 32 metres it gave a supply of 397 cubic metres per day, with 3·55 per cent. of solid matter and with a temperature of 26° R. The 'Alte Kurbrunnen,' known as No. 6, was situated about 100 yards further east, and at 19 metres produced a similar spring with temperature 18° R.

The great boring made in 1839, No. 7, going down to a depth of 159 metres, shares with the last of all (12) the responsibility of supplying the great system of baths. It had been carried down to a depth of 159 metres when, as there was no result, the works were abandoned. In December, 1846, after violent thunderstorms and heavy rains lasting for some days, there was a sudden rush of water up the deserted shaft, and the supply has never stopped since. The water contains a large quantity of carbon dioxide, and solids to the extent of 3·5 per cent., with a temperature of 26–29 R.

Numbers 8 and 9 were experimental borings made a short distance to the northward (between the 'Waitz' tower and the Teich); but the temperature of the water was much lower and the general result unsatisfactory.

The tenth attempt, made a mile south by the third 'gradirwerk,' could only be carried to 65 metres, when it gave an effervescent water with much bicarbonate of soda. It is much used as a medicinal drinking water, and is known as the Ludwig's Quelle (Ludwigsbrunnen).

The eleventh was a small boring 29 metres deep, which subsequently ceased to give any supply.

Lastly, the twelfth, now the Friedrich-Wilhelm's Quelle, was bored in 1855 to a depth of 180 metres, with an 18 cm. diameter. The water did not rise spontaneously at first, and two hand-pumps were employed. In about half an hour a column of water charged with carbon dioxide rose suddenly in the boring, blowing up the pumping apparatus and rising 16 metres above the ground. It was found to give 1,214 cubic metres in the 24 hours, with a temperature of 30° R. and 4·3 per cent. of dissolved solids. The boring is situated only 4 metres east of No. 7, and the two together supply practically the whole bath system. The ordinary thermal brine baths are derived mainly from 12, but there are underground pipes from both sources to supply the effervescent baths, or 'sprudel-bäder,' in the bath-houses 1 and 5.

[1] In the plan (Fig. 3) I have unfortunately numbered these four from west to east, instead of in the reverse order, as correctly shown in the sections (Figs. 4 and 5), but their close proximity and the fact that 2 is the only deep one renders the error of no importance.

Such is a brief summary of the history and nature of the Nauheim borings. From the geologist's point of view the features of interest fall into two series: first, the strata traversed by the borings; and second, the temperature and contents of the waters themselves.

The former question may be more conveniently dealt with in the concluding section of this paper, but it may be noted, in passing, that those borings which are likely to give most help in explaining the subterranean structure are Nos. 1–7, 11, and 12. An almost straight line can be drawn through these, approximately at right angles to the general strike of the rocks.

The results of chemical analysis of the contents of the different springs are given in many of the books of local and medical information published on the spot, and there is no necessity to investigate the numerous variations here. With a view to geological considerations, however, it may be well to reproduce the details of one typical analysis, that of the Friedrich-Wilhelm's Quelle (No. 12).

Amount per 1,000 Grammes of Water.[1]

Sodium chloride	29·29
Lithium chloride	·05
Potassium chloride	1·11
Ammonium chloride	·07
Calcium chloride	2·32
Magnesium chloride	·52
Calcium sulphate	·03
Strontium sulphate	·04
Calcium carbonate	2·60
Iron carbonate	·04
Silica	·02

At the risk of seeming to break the promise given above to keep entirely to such matters of detailed description as bear on the geology of the district, I am tempted to insert here a note on the process by which the concentrated brine, and subsequently the dry salts, are obtained. It is distinctly difficult at first for the enquiring visitor to understand the meaning of the curious structures round the town; and the process is not only interesting from the commercial, chemical, and mechanical points of view, but in some of its features is very suggestive to the biologist and geologist as well.

About the middle of the century the old method of simple evaporation in troughs was discarded and a more elaborate system adopted. A short distance south of the town a number of long tanks across the plain of the Usa were constructed, and above each an immense erection of heavy timber frameworks. The interspaces of these massive structures are entirely filled in with what may in general be termed 'brushwood,' but which consists almost entirely of close-packed bushes of blackthorn. Along the top of each of these 'gradirwerke,' as they are termed, runs a trough containing the water from the springs with nearly all its lime, iron, and salts; and this is allowed to percolate down through the brushwood

[1] These are the chief constituents of the dissolved solids. There are traces of various other substances, but those given here are such as can be recorded in the second decimal place.

masses below. As the water trickles over the twigs the lime and remaining iron oxides are deposited as a stalagmitic crust upon the wood; but the more soluble salts remain, and the water which drips into the underlying tank is a more or less concentrated brine.

Such is the principle of the process, but it takes one a little time on the spot to discover how the mechanical difficulties are overcome. The method seems to be this. The saline waters from the two great 'sprudels' are directed into an open trench, which empties them into a large round tank situated in the fields south of the town. To raise this water to the top of the 'gradirwerke' would appear a difficult task; and yet, in spite of the flat country, the very small quantity of water in the Usa, and the almost imperceptible current, it is performed by means of two water-wheels. The three western 'works' are supplied by a large double pump by the Ludwig's Quelle. There is not sufficient force of water to turn the wheel directly, but having been once started it is able to pump up sufficient water to resupply itself as well as to pass on the remainder up two great pipes to the top of the framework. The eastern 'works' are similarly supplied, but in this case the wheel is as far away as the village of Schwalheim beyond the railway on the east. The 'connecting-rod,' if such it can be called, between the wheel and the nearest of the Gradirwerke is a long series of hollowed tree trunks placed end to end. These are supported at intervals on the axles of pairs of iron wheels, which run on rails laid on the top of low stone walls. The whole row moves backward and forward some eighteen inches with the turning of the wheel. A mechanical system distinctly cumbrous, but as there is no haste necessary in the process it is probably as effective as any other and more economical.

The first of the solid contents of the spring water to separate are the iron oxides, with which the basin of the Great Sprudel is coated. In the trench leading off the waters to the Gradirwerke there is a similar deposit of a powdery red oxide on twigs, leaves, etc., that have fallen in. With the exception of a few diatoms and filaments of cyanophyceous algæ there seems little life here. I had expected to find *Leptothrix ochracea*, but was unsuccessful. Further on, when the lime begins to precipitate, a red porous 'travertine' is produced. Almost all the remaining iron seems removed after passing the tank, as the stalagmite on the brushwood is very rarely tinged with red.

At the present time there is little evident incrustation of the brushwood, owing to its having been comparatively recently renewed,[1] but the lately removed material often shows a crust nearly two inches in thickness, and blocks of it are used all over the neighbourhood as ornamental rockwork for gardens.

In the western salines the brine, freed from lime and iron, undergoes some evaporation, and at times very delicate, hollow, salt stalactites are formed, as well as imperfect or hollow salt crystals like the 'hopper-shaped' crystals, seen by evaporation

[1] I understand that the period of renewal is about every ten years.

of salt solution under the microscope. The brine in the tank at this point is clear, and contains but little life. A few floating patches of a green alga (*Rhizoclonium*?) are, however, generally present.

In the last or most westerly tank the appearance is very different. The water has a stagnant and turbid aspect, and is often covered with bacterial scum. Dense masses of *Vaucheria* form rounded cushion-like growths at the bottom, and the filaments become completely incrusted except at the growing tips. If these had been formed under natural conditions, and subsequent infiltration by lime had occurred, a formation would be produced which can be paralleled by the oblique limestones already referred to as found at Bönstadt in the Northern Wetterau.

The algal masses are crowded in the spring by larval cases of a dipterous insect, some half an inch long, and later in the year the surface of the water swarms with small black flies. As the cases become similarly incrusted they would contribute to rock formation and produce a rich 'indusial' limestone deposit. As the water here contains a high percentage of salts the luxuriant growth of these two organisms is remarkable; and doubtless microscopic study, which I was unable to undertake, will reveal other forms of interest.

V. Geological Problems involved.

Leaving here this brief description of the distribution of the various formations and of the general character of the springs

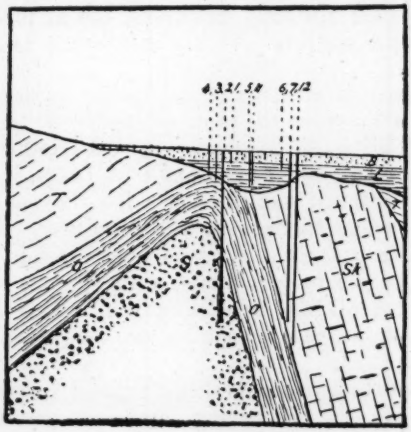


Fig. 4.—Geological explanation of the data furnished by the borings as given by Dieffenbach (Desc. of Geol. Map of Hesse, Darmstadt, 1856).

B. Blättersandstein.	L. Litorinellen-kalk.
T. Taunus-quarzit.	S. Spiriferen-sandstein.
O. Orthoceras-schiefer.	S.k. Stringocephalen-kalk.

and borings, we may turn, in conclusion, to some consideration of the geological problems involved. The chief of these may be enumerated as follows:—(*a*) the underground structure as indicated

by the data given by the borings; (*b*) the extent and character of the ancient lake; (*c*) the reasons for the chemical and physical characteristics of the springs; and (*d*) the connection between the eruptive rocks and the general phenomena of the district.

In discussing these points it is scarcely possible in any case to make dogmatic statements, and the following remarks must be regarded only as a statement of the case for investigation.

(*a*) When one examines the published details of the different borings one cannot fail to be struck by the wide differences which exist, in so small an area, between the depths at which the Palæozoic rocks were encountered.

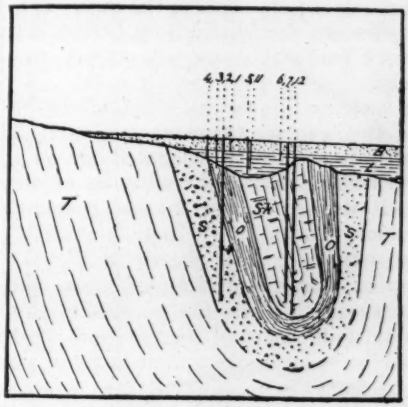


FIG. 5.—Geological explanation of the data furnished by the borings here suggested.

B. Blättersandstein.	L. Litorinellen-kalk.
T. Taunus-quarzit.	S. Spiriferen-sandstein.
O. Orthoceras-schiefer.	S.k. Stringocephalen-kalk.

Although the Devonian rocks of the Johannisberg are dipping south-east at a high angle where they disappear below the Tertiary beds, and are met with at 120 m. in boring 4, yet they are not touched at all in borings 5 and 11. The deep boring 2, on the other hand, while it meets Palæozoic rock at 130 m., does not touch the Taunus-quarzit, but traverses some 165 m. of 'Orthoceras-schiefer' and terminates in 'Spiriferen-sandstein.' Borings 7 and 12, on the other hand, strike the 'Stringocephalen-kalk' immediately below the Tertiaries, and terminate in that formation.

These facts appear to show that in the first place the old land-surface on which the Tertiary beds were deposited has a distinctly irregular contour, and secondly, that by some agency, either folding or faulting, the members of the Middle Devonian series are present under Nauheim at no great depth, but with very limited horizontal extension.

The explanatory section published in connection with the old geological map, a copy of part of which is given on p. 351, looks

fairly satisfactory at first sight, but on study is found to contain serious difficulties. The 'Stringocephalen-kalk' on the right can hardly be accounted for without any corresponding mass on the left; and the theory requires that the dip of the 'Taunus-quarzit' on the east slope of the Johannisberg should be represented in exactly the reverse direction to what is actually the case. More serious still is the difficulty that it places the 'Taunus-quarzit' above the other members of the Devonian, whereas it really underlies all but the 'Sericit-schiefer.'

Under these circumstances I thought one might try to make a hypothetical section which would better fit in with the known data; and it seems to me that some such structure as is shown in Fig. 5 would meet the requirements of the case. It is not necessarily true, as there may be considerable faulting, but until there is evidence of the presence of faults it is as well to try to explain matters without their help.

An infolding such as this is just what might be expected from the structure of the Taunus range as a whole. The peculiarities of the boring records are easily accounted for on this supposition, and several other isolated facts fall readily into place. Thus, if it is true that boring 10 in the plain on the east passed through 'Sericit-schiefer' and then touched the 'Taunus-quarzit,' such is what might have been expected, as is shown in Fig. 5. Similarly, the reported outcrop of 'Orthoceras-schiefer' near the Teich-haus is by no means impossible; while the patches of the same rock and of 'Spiriferen-sandstein' mapped to the west of Ober Mörlen can also be accounted for as an infold similar to that below Nauheim.

(*b*) Passing on from the question of these contorted Devonians to the simply and conformably stratified Tertiary beds of the Wetterau plains, one expects a simplification of the task of explanation. Such there is to a certain extent; but, on the other hand, there are new questions of a totally different character which crop up in the endeavour to follow out the history of the country.

While there can be no doubt that the area over which these deposits extend was in Middle Tertiary times an enclosed lake, yet the stages which preceded the isolation of this extent of water are not so easily recognizable.

The fact that mollusca characteristic of brackish water—such as *Cyrena*, *Cerithium*, and *Litorinella*—are found in beds as high as the Blättersandstein, is somewhat remarkable in itself. When we find, moreover, that in the deeper layers there is a much larger percentage of such types, and finally in the lowest strata we have to deal with typically marine genera, it is evident that the succession of beds records a series of great physiographic changes. It seems almost certain that in Oligocene times these districts were covered by sea-waters from the south; and the contours of Central and Northern Europe suggest a similar communication with the ocean on the north.

It seems probable that the district was a dry land area, while the Cretaceous rocks of other parts of Germany were being deposited; that an Eocene or post-Eocene subsidence let in the sea-water from

a long northward extension of the Mediterranean reaching from the Marseilles neighbourhood up the Rhône and Rhine valleys, perhaps establishing communication with the North Sea; and that the earth-movements which subsequently completed the upheaval of the Alpine chain separated the northern gulf from the sea to which it had formerly belonged.

The process of severance was doubtless gradual, and allowed of a transition period in which the marine *Murex* and *Perna* were slowly displaced by the brackish-water *Cerithium* and *Cyrena*. In the upper strata there are narrow bands in which the fossils indicate the prevalence of purely fresh-water conditions, but the brackish-water types continued to exist apparently through Miocene times.

(*c*) As to the chemical and physical questions connected with the Nauheim springs, anything like a complete discussion is beyond the scope of this paper. Those who wish to know how far the consideration of the amount of soluble salts in springs, rivers, and seas may lead them in the discussion of the geological age of our planet, should read Professor Joly's interesting paper in the Transactions of the Royal Dublin Society for 1899.

So far as the local questions are concerned we can only make a note or two on, firstly, the chemical contents, and secondly, the physical conditions.

In the first case it is evident that we are not dealing with 'special' types of springs—saline, chalybeate, or calcareous—but with a combination of all. It would be interesting to know the sources of the different contents, but it is difficult to make anything but the vaguest suggestions.

As to the iron, it is evident that a certain amount may come from denudation of the Devonian rocks on the west, and more from the breaking up of the basalts. The extraordinary amount of iron oxides in some beds of the 'Blättersandstein' suggests that they may have contributed large quantities to the underground supply from which the springs now rise, but they, in turn, must have derived it from neighbouring Palæozoic or igneous rocks in Tertiary times.

With respect, again, to the calcareous contents, there seems a much larger proportion than the geological features of the surrounding country would lead one to expect. The limestone strata are of small extent, and anything contributed by the decomposition of the felspars in the basalt would be insignificant. There is, on the other hand, a great quantity of calcareous matter in the Tertiary beds, derived at that date, most likely, from a greater distance and from a larger extent of since denuded limestone in the district. Much of this has been and is still being gradually carried down through fissures to the subterranean reservoirs which the borings have 'tapped.' The lime was doubtless largely separated through the agency of organisms, but in beds of this character the shells would almost certainly be to a large extent redissolved.

It is possible, however, that we have not here sufficient to account for the surface phenomena, especially when we also take into consideration the enormous amount of carbon dioxide in the waters of the Sprudel. Probably there are deep-seated calcareous strata,

beyond the reach of the borings, where a high temperature prevails and intense chemical reaction is still in progress.

The soluble saline constituents again offer us much the same problem. The physiographic changes of Tertiary times must have been slow, gradual, and constantly varying, and the alternations of marine, brackish, and fresh-water conditions probably resulted in a large residue of salt in the strata then being deposited. The minerals present in such formations as the Blättersandstein certainly suggest this; but whether or not such a residue is still present, a vast amount has probably been washed down into the subjacent rocks.

If this be considered insufficient as a source of the present regular supply, one is obliged to fall back again on the supposition that there exist below the deepest borings either great salt beds or a stratum of immense chemical activity.

Turning from the question of chemical contents to that of physical conditions, one meets again with questions more easily asked than answered. The most obvious are the cause of the high temperature of the waters, and the reason for their expulsion. As to the former one might suggest a very great depth of origin, but we have no evidence that these springs rise from a stratum deep-seated enough to account alone for their heat. Mechanical pressure, added to such strong chemical activity as may exist at a relatively high level in the earth's crust, even locally, might also account for it in part. In addition to such conditions, however, we have to remember the proximity of great basaltic masses which were themselves in a state of fusion at a period not, geologically speaking, so very remote. As the presence of thermal springs is so commonly correlated all the world over with the existence of comparatively recent volcanic action, it is probable that we are safe in here regarding the present temperature of the brine-springs as residual from volcanic times.

With respect to the cause of the expulsive force with which the waters of the two great 'sprudels' are thrown up, it seems that the German geologists, as a rule, are inclined to follow their great leader Bunsen, who studied the district early in the century and ascribed the effects entirely to the freeing of the carbon dioxide.

That the sudden liberation of gas, with the diminishing pressure as the water rises in the tube, must have a very great effect in producing the violence of the final escape, cannot be denied; but this does not necessarily justify a neglect of hydraulic pressure altogether. The great drainage area of the Taunus, its large rainfall, and the fissures and cavities it contains all seem to suggest the probability of a very efficient hydraulic system at work; and the history of the Great Sprudel, where the first outburst only occurred some years after the construction of the boring, as a consequence of heavy rains, would appear to support this view.

Also, as Professor Cole has pointed out to me, why neglect 'residual pressure'? Just as we may attribute high temperature to the survival, *in extremis*, of volcanic conditions, so the tectonic 'Alpine' movements are not to be regarded as entirely dead, but the remaining strains and pressures in the earth's crust may still be factors in the ejection of these heated waters.

(*d*) With regard, lastly, to the agency of the basaltic eruptions, the considerations involved have been already referred to, and my own observations have been too limited to permit of a definite opinion. A superficial study of the country would lead one to the

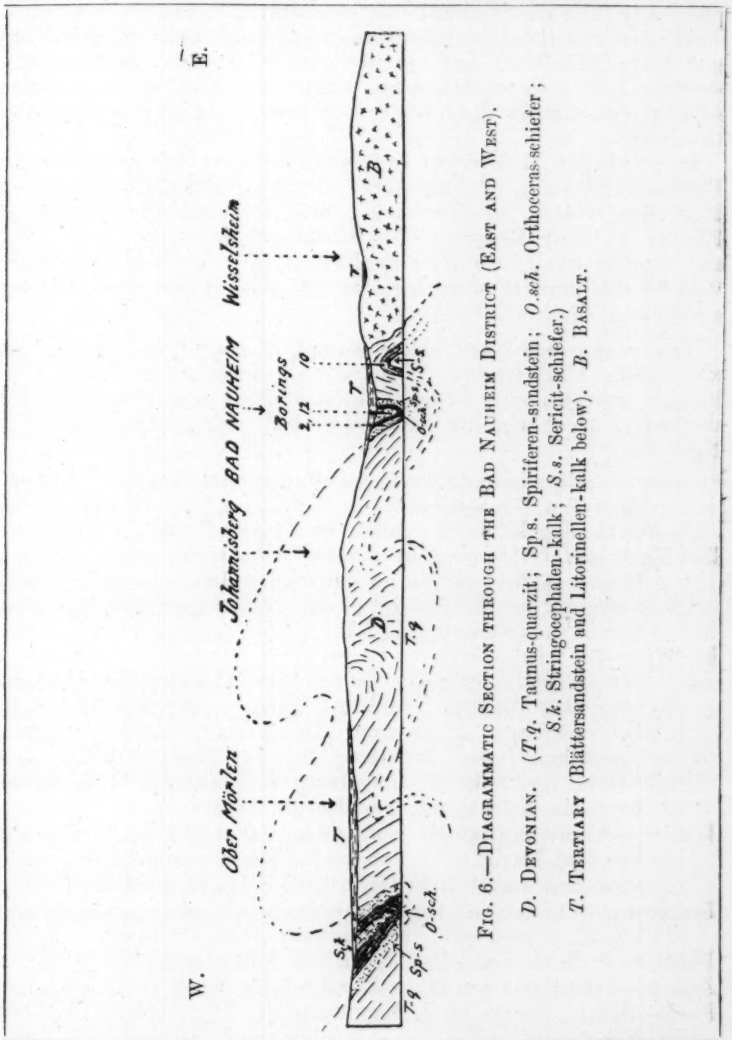


FIG. 6.—DIAGRAMMATIC SECTION THROUGH THE BAD NAUHEIM DISTRICT (EAST AND WEST).

D. DEVONIAN. (*T.q.* Taunus-quarzit; *Sp.s.* Spiriferen-sandstein; *O.sch.* Orthoceras-schiefer; *S.k.* Stringocephalen-kalk; *S.s.* Sericit-schiefer.)

T. TERTIARY (Blättersandstein and Litorinellen-kalk below). *B.* BASALT.

conclusion that the basaltic masses had been consolidated before the Oligocene seas or lakes deposited sediments round their bases, and that they formed islands in the waters of Middle Tertiary times.

There is, however, I understand, evidence elsewhere for the Miocene age[1] of the eruptions, and of a still later date for part of

[1] See note on p. 355.

those of the Vogelsgebirge. One can only conclude that the patches in the immediate neighbourhood of Bad Nauheim represent lava-flows at a considerable distance from the active centres, and that they forced their way through the sedimentary rock, with comparatively little disturbance or metamorphism.

The fact that there are reappearances of basalt between Homburg and Ober Erlenburg and on towards Wiesbaden, suggests the existence of a very wide zone which may have a far greater subterranean extent than the minor surface exposures lead one to expect.

In conclusion, I have to express my thanks for assistance to Professor Kinkelin, of Frankfurt; Professor Brauns, of Giessen; Professor Wittich, of Darmstadt; and Professor Denckmann, of Berlin; to Herr Bergrath Otto Weiss, of Nauheim; and lastly, and very gratefully, to Herr Sanitätsrath Dr. Ferdinand Credner, who, in the interests of geology, treated with a generous leniency a somewhat disobedient patient.

The works mentioned below cannot, of course, be regarded as a complete bibliography. I have only recorded such as were brought to my notice during a brief visit as a starting-point for the next student who has the good or bad luck to find himself at Nauheim.

"Geologische Specialkarte des Grossherzogthume Hessen." Descriptions of (*a*) Giessen section by *Dieffenbach*, 1856; (*b*) Friedberg (including Nauheim) section by *Ludwig*, 1855.

Bad Nauheim: Guide by *Herr Bergrath Otto Weiss & Dr. Groedel*, 1888. (This edition is mentioned here as it contains a chapter on the geology of the district more complete than that of the ordinary guides.)

Kinkelin.—(*a*) "Erläuterungen zu den geologischen Übersichtskarten der Gegend zwischen Taunus und Spessart": Senckenbergischer Bericht, Frankfurt, 1889. (*b*) "Die Tertiär u. Diluvialablag. d. unteren Mainthales": Abh. z. geol. Specialkarte von Preussen, Bd. ix, Heft 4, 1892. (*c*) "Geol. Tektonik d. Umgebung v. Frankfurt": Senckenbergische Naturforsch. Gesellschaft, 1885.

Wittich.—"Bericht über die geologische Aufnahme der Umgegend von Bad Nauheim": Vereins für Erdkunde und der Grossh. geol. Landesanstalt zu Darmstadt, Folge iv, Heft 19, 1898.

Denckmann.—"Silur und Unterdevon im Kellerwalde": Jahrb. der königl. preuss. geol. Landesanstalt, 1896.

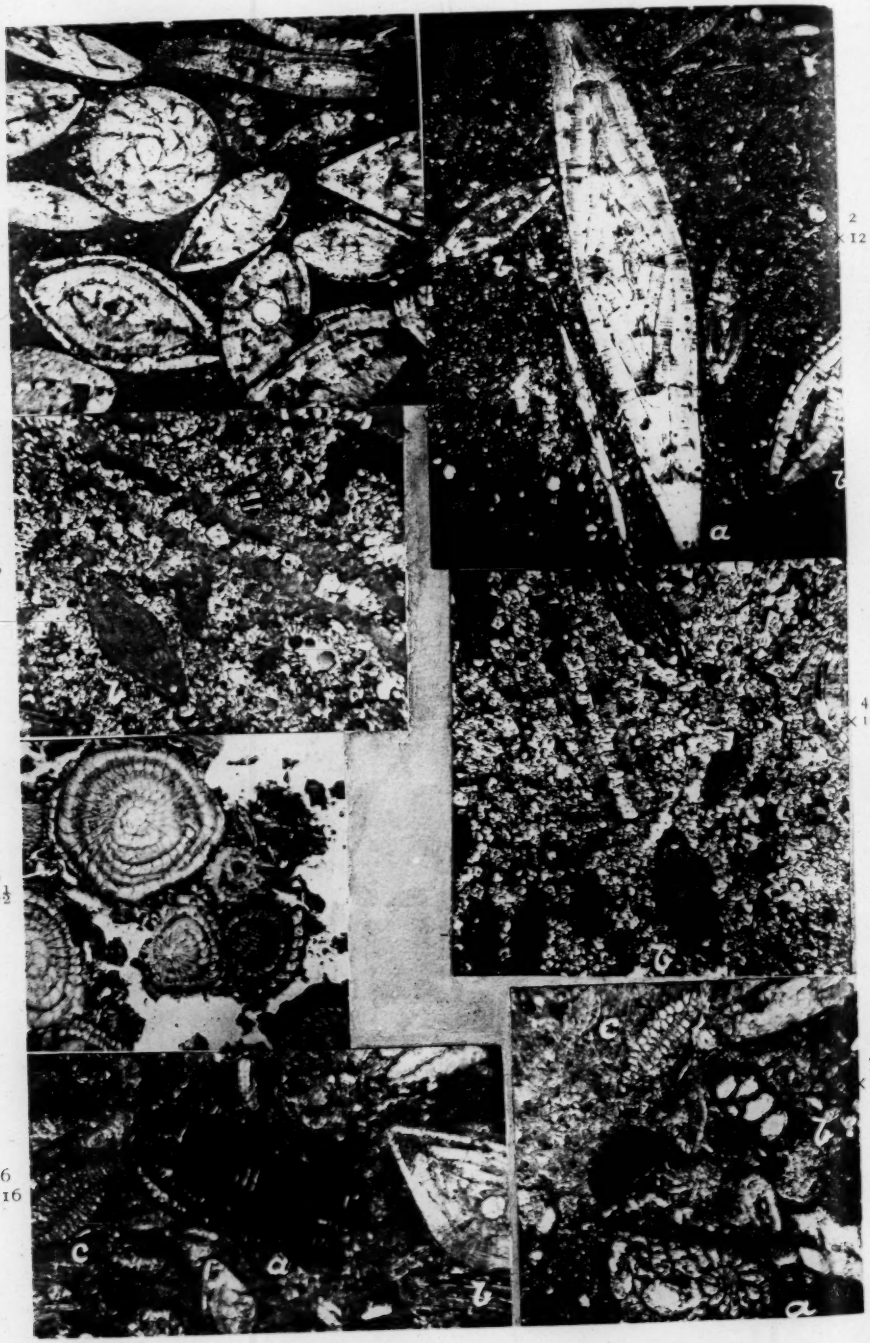
Wagner.—"Chronik von Bad Nauheim," Nauheim, 1897.

Lepsius.—"Geologie von Deutschland," Bd. i (1892).

Koch.—Jahrb. Preuss. Geol. Landesanstalt, Bd. i (1881), Taf. vi, Fig. 1.

Bunsen. — Stud. der Göttingischen Vereins Bergmännischen Freunde, Bd. iv, Heft 3 ("Über de Nauheimer Thermalquellen").

Bromeis. — Jahresbericht. d. Wetterauischen Gesellschaft f. d. Naturkund. ("Grosse Soolsprudel v. Nauheim").



F. C. Photo.

TERTIARY FORAMINIFERAL LIMESTONES FROM SINAI.

III.—Tertiary Foraminiferal Limestones from Sinai.

By Frederick Chapman, A.L.S., F.R.M.S.

(PLATES XIII and XIV.)

(*Concluded from the July Number, p.* 316.)

Nummulites, Lamarck [1801].

Preliminary remarks on the genus.—The interesting observations on the dimorphism of the genus *Nummulites*, which have been made from time to time by special investigators, such as Von Hantken, Munier-Chalmas & Schlumberger, De la Harpe, Rupert Jones, and Van den Broeck, have resulted in the establishment of couples of so-called species, constituting a species in the zoological sense, in which the smaller form, with a large central chamber, is referred to as form A, whilst form B usually has a larger test and invariably possesses a diminutive central chamber. The two forms are otherwise spoken of as the megalospheric and microspheric forms. In some cases there may be little doubt as to the accuracy of the assignment of the two forms to one species, especially since they may be the only examples present in the rock. In the case of a stratum containing more than two species, however, there may be no small difficulty in coupling the actual forms which constitute the species, for there is often little in either the internal or external characters to guide one in linking the forms. In our present state of knowledge, therefore, it appears to be most convenient to describe the forms under their specific denominations as already known, at the same time pointing out their relationship to one another. Some good suggestions as to the naming of Nummulites and other Foraminifera which exhibit the two modes of growth and shell form have lately been made by Dr. A. Silvestri.[1]

With regard to the older method of grouping the Nummulites according to their superficial appearance and texture, this can be at the best only an artificial method of arrangement, for it sometimes happens that two different forms constituting a zoological species may be found to belong to two of the separated so-called groups; as, for instance, *N. curvispira*, which has been placed in the granulate group, and *N. complanata* or *N. complanata*, var. *Pachoi*, in the group of smooth forms. Moreover, it will be seen by referring to Rupert Jones' Catalogue of Fossil Foraminifera in the British Museum,[2] that *N. curvispira* is an example of the granulate group which does not invariably exhibit the characters ascribed to it.

Nummulites planulata (Lamarck). (Pl. XIII, Fig. 2*a*.)

Lenticulites planulata, Lamarck, 1804: Annales du Muséum, vol. v, p. 187.
Nummulites planulata (d'Orb.), d'Archiac & Haime, 1853: Descr. Anim. groupe nummulitique Inde, vol. i, p. 142, pl. ix, figs. 5*a*, 6*a–c*, 7*a–h*, 8*a–d*, 9*a*, *b*, 10*a–c*.

One recognizes this form by the minute or almost invisible central chamber, and the flatness of the test. In section it exhibits from

[1] Atti dell' Accad. Pont. Nuovi Lincei, Anno liii (1900), pp. 1–10. See also Van den Broeck: Bull. Soc. Belge Géol. Pal. Hydr., vol. x (1896), 1899.
[2] Op. cit., pp. 46, 47, specimens P 1014 and P 890.

four to six whorls, which increase rapidly in breadth (in median section), especially towards the last.

The specimens here dealt with are very typical when compared with d'Archiac's figures. Those forms of the same group or type recorded by De la Harpe from Egypt[1] differ chiefly in their umbonate centre and comparatively sharp peripheral edge.

N. planulata appears to be distributed chiefly through the Lower and Middle Eocene beds of Europe, but it is occasionally found with a higher range. This species has been recorded by Dr. Fraas from Egypt.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l*. ? Bartonian (Upper Eocene) or ? top of Mokattam Series (Middle Eocene) : Jebel Abyad, beach deposit (later). Common.

***Nummulites Guettardi*, d'Archiac & Haime, var. *antiqua*, De la Harpe.** (Pl. XIII, Fig. 6*b*.)

Nummulites Guettardi, d'Archiac, var. *antiqua*, De la Harpe, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 172, pl. xxx (i), figs. 37–42.

The central chamber in our specimens from Sinai is fairly large, agreeing in this particular with the typical examples of the species figured by d'Archiac.[2] De la Harpe, however, states that his specimens have a small central chamber, so that it is possible that we have here the two forms A and B confused by the above-named authors.

The variety *antiqua* differs from the typical *N. Guettardi* in having a lenticular and more compressed shell. The type form was found by De la Harpe only in the Upper Eocene beds of Egypt.

The above variety was found by De la Harpe in rocks of the Libyan Series (Lower Eocene) of Nekeb, east of Farâfrah, and of El-Guss-Abu-Said.

Coll. Geol. Surv. Egypt, No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene) : Jebel Krer, Sinai (same range as Jebel Abyad). Common.

***Nummulites Ramondi*, Defrance.** (Pl. XIII, Figs. 3*b*, 4*b*.)

N. Ramondi, Defrance, 1825 : Dict. Sci. Nat., vol. xxxv, p. 224. D'Archiac & Haime, 1853 : Descr. Anim. groupe nummulitique Inde, vol. i, p. 128, pl. vii, figs. 13*a–d*, 14*a*, 15*a*, 16*a*, 17*a*, *b*.

This is a small species, but has no large central chamber. The peripheral edge is sharper than that of *N. Guettardi*, and the test is much thinner.

N. Ramondi is one of the most widely distributed of the nummulites; amongst many localities it has been found in France, the Alps, the Pyrenees, Egypt, the Crimea, and India. From Egypt De la Harpe obtained it in the Lower Libyan Series of Jebel Têr.

Coll. Geol. Surv. Egypt, Nos. 4,113 and 4,135, Box Nos. 4*l* and 3*l* respectively. Libyan Series (Lower Eocene) : junction of Wadi

[1] Palæontographica, vol. xxx (1883), Pal. Theil, pp. 161–4, pl. xxx, figs. 1–18 : *N. Fraasi*, *N. Rütimeyeri*, and *N. Chavannesi*.

[2] Descr. Anim. groupe nummulitique Inde, vol. i (1853), p. 130, pl. vii, figs. 18*a–e*, 19*a*, *b*.

Baba and Wadi Shellál, Sinai. Common. ? No. 3,598, Box No. 13*l*. Mokattam Series (Middle Eocene): Wadi Khadáhid. Rare.

Nummulites Heberti, d'Archiac & Haime.

Nummulites Heberti, d'Archiac & Haime, 1853: Descr. groupe nummulitique Inde, vol. i, p. 147, pl. ix, figs. 14*a–g*, 15*a*. De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 178, pl. xxxi (ii), figs. 26, 27.

This is a very minute nummulite, having an umbonate centre and a sharp peripheral edge. The central chamber is almost invisible. The specimens from Sinai measure about 2 mm. in diameter and ·85 mm. in thickness. *N. Heberti* was found by Schwager in both the Libyan and Bartonian Series of Egypt.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l*. ? Bartonian (Upper Eocene) or ? top of Mokattam Series (Middle Eocene): Jebel Abyad, Sinai, beach deposit (later). Frequent. Also No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene): Jebel Krer (same range as Jebel Abyad), Sinai. Rare.

Nummulites variolaria (Lamarck). (Pl. XIII, Fig. 2*b*.)

Lenticulites variolaria, Lamarck, 1804: Ann. du Muséum, vol. v, p. 187, No. 2.
Nummularia variolaria (Lam.), Sowerby, 1829: Mineral Conchology, vol. vi, p. 76, pl. DXXXVIII, fig. 3.
Nummulites variolaria (Sow.), d'Archiac & Haime, 1853: Descr. Anim. groupe nummulitique Inde, vol. i, p. 146, pl. ix, figs. 13*a–g*.
N. variolaria (Lam.), De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 179, pl. xxxi (ii), figs. 28–36.

This is one of the most widely distributed nummulites. It occurs in Hampshire, near Brussels, Biarritz, in Hungary, Asia Minor, Kurdistan, etc. It is usually characteristic of the Middle and Upper Eocene. In Egypt it has been found in the Lower and Upper Eocene (De la Harpe).

It is fairly common in the specimen from Sinai, No. 4,112, and is associated with *N. planulata*. The characters by which one recognizes it in section are the lenticular outline and sharp peripheral edges. In the tangential aspect the sections exhibit the regularly striated shell surface. The central chamber is moderately large.

Coll. Geol. Surv. Egypt, No. 4,112, Box No. 2*l*. ? Bartonian Series (Upper Eocene) or ? top of Mokattam Series (Middle Eocene): beach deposit, Jebel Abyad, Sinai. Frequent.

Nummulites subdiscorbina, De la Harpe. (Pl. XIII, Fig. 1.)

Nummulites subdiscorbina, De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 185, pl. xxxii (iii), figs. 8–15.

This species is not unlike *N. Guettardi*, var. *antiqua*, but differs in the greater proportionate breadth of the test; it also exhibits strongly developed double cones of tubuli at the umbilical axis. This species is relatively larger than *N. Guettardi*, var. *antiqua*.

De la Harpe states that *N. subdiscorbina* usually accompanies the larger species *N. discorbina*, but this is not the case with those of the Sinaitic limestones. The Egyptian specimens were found near Cairo, at Beni Hassan and Minieh.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai. Abundant.

The group of *Nummulites Gizehensis* (Forskål), Ehrenberg.

From a zoological standpoint the various forms of nummulites so closely associated in certain beds of the Mokattam Series in Egypt and neighbouring areas, referred to under the name of *N. Gizehensis* and its varieties, are clearly local modifications of the more widely distributed *Nummulites complanata*, Lamarck. In consideration of the practical use of distinctive terms for local varieties in relation to their stratigraphical distribution, it is here proposed to retain the grouping of this series so minutely and carefully worked out by Dr. De la Harpe.

Nummulites Gizehensis (Forskål), Ehrenberg, var. *Ehrenbergi*, De la Harpe. (Pl. XIV, Fig. 15.)

Nautilus Gyzehensis, Forskål, 1775: Descriptiones Animalium, p. 140. 1776: Icones rerum naturalium, etc.

Nummulites Gyzehensis, Ehrenberg, 1838: Abhandl. Akad. Wiss. Berlin, p. 93.

N. Gyzehensis, Ehr., d'Archiac & Haime, 1853: Descr. Anim. groupe nummulitique Inde, vol. i, p. 94, pl. ii, figs. 6*a–f*, 7*a*, 8.

N. Gizehensis Ehrenbergi, De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 190, pl. xxxii, figs. 16–25; pl. xxxiii, figs. 1, 2.

This is the well-known form with the thick disc and rounded edge. The septa between each chamber are unusually thick and inclined.

This variety has been chiefly obtained from Egypt, but it has also been recorded from Sinai, Syria, Anatolia, and Vicentin. In Sinai it occurred at Wady Gharandel (Rupert Jones and Bauerman). It has also been doubtfully recorded from Biarritz.

Coll. Geol. Surv. Egypt, No. 4,163, Box No. 5*l*. Mokattam Series (Middle Eocene): near top of Jebel Safariat, Sinai. Several specimens.

Nummulites Gizehensis (Forskål), Ehrenberg, var. *Lyelli*, d'Archiac & Haime. (Pl. XIV, Fig. 14.)

Nummulites Lyelli (pars), d'Archiac & Haime, 1853: Descr. Anim. groupe nummulitique Inde, vol. i, p. 95, pl. iii, figs. 1*a*, *b*, 2. Fraas, 1867: Aus dem Orient, p. 129.

N. Gizehensis Lyelli, d'Archiac, De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 192, pl. xxxiii (iv), figs. 3–10.

This is a large variety, and perhaps approaches the type *N. complanata* most closely. It is rather regular in outward form, and has the peripheral edge fairly sharp and thin. The septa, seen in section, run nearly straight across from whorl to whorl, especially in the later turns of the shell, instead of being arcuate and inclined, as in the variety previously mentioned. The chambers are irregularly spaced. The specimens from Sinai measure as much as 38 mm. in diameter and about 6 mm. in thickness.

N. Gizehensis, var. *Lyelli*, has been recorded from Egypt, near Cairo; and from Syria, in the white limestone of Gerizhem.

Coll. Geol. Surv. Egypt, No. 4,163, Box No. 5*l*. Mokattam Series (Middle Eocene): near top of Jebel Safariat, Sinai. Very common.

Nummulites Gizehensis (Forskål), Ehrenberg, var. *Pachoi*, De la Harpe.

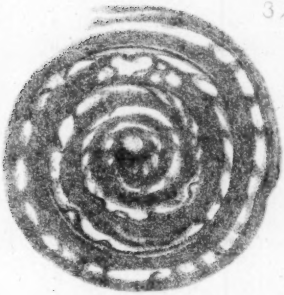
Nummulites Gizehensis Pachoi, De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 193, pl. xxxiii (iv), figs. 14–18; pl. xxxiv (v), figs. 1–5.

1 x 30

3 x 15

4 x 30

5 x 30


2 x 15

6 x 30

10 a x 30

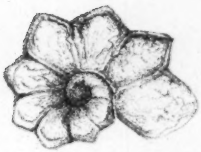
7 x 30

10 b x 30

8 x 30

9 x 30

12 x 3

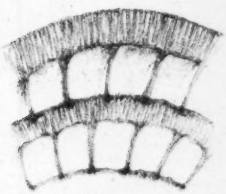

11 x 15

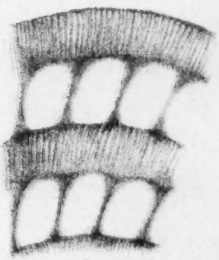
13 x 3

16a x 2

16b x 2

16c x 2


14 x 15


15 x 15

F. Chapman del. ad nat.
C. M. Woodward lith.

West, Newman imp.

Eocene Foraminifera from Sinai

This variety is large, or moderately large compared with others of the same type; discoid, compressed, and with rounded, blunt, or sharp edges. The cross section shows the sides to be parallel.

De la Harpe has recorded this variety from the Pyramids of Gizeh, in the Wadi Emsîd-el-Flûs, between Mêr and Farâfrah, on the Gâret-el-Dalleh, and near Rajân, between the Fajûm and Beharieh.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai. Frequent. No. 4,163, Box No. 5*l*. Mokattam Series (Middle Eocene): near top of Jebel Safariat, Sinai. Frequent. Also No. 3,598, Box No. 13*l*. Mokattam Series (Middle Eocene): Wadi Khadâhid, Sinai. Frequent.

Nummulites curvispira, Savi & Meneghini. (Pl. XIII, Fig. 5.)

Nummulina curvispira, Savi & Meneghini, 1851: Consid. Geol. Toscana, p. 137.
Nummulites curvispira (Menegh.), d'Archiac & Haime, 1853: Descr. Anim. groupe nummulitique Inde, p. 127, pl. vi, figs. 15*a–d*. Fraas, 1867: Aus dem Orient, p. 130. De la Harpe, 1883: Palæontographica, vol. xxx, Pal. Theil, p. 200, pl. xxxiv (v), figs. 42–67.

This nummulite, although very variable, is generally of a flattened lenticular shape, with rounded peripheral edge, sometimes more or less sharp. In the latter feature it approaches *N. Rouaulti*, d'Arch. and Haime. Clean fresh specimens often show the flexuose striation which is characteristic of *N. Gizehensis*. The surface of specimens slightly weathered is radially or sinuously striate, with granulations sparsely scattered between them. The central chamber is usually very large, and is followed by a semilunar segment. The whorls are somewhat irregular, and there are usually six turns on a radius of 3 mm. The chambers are elongate and greatly curved.

N. curvispira has already been recorded from Sinai (Wadi Gharandel) by Rupert Jones. It is commonly found at most of the localities in Egypt in the Mokattam Series, at Mokattam, Gizeh, Minieh, Beni Hassan, and the Libyan Desert.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai. Frequent. No. 3,598, Box No. 13*l*. Mokattam Series (Middle Eocene): Wadi Khadâhid, Sinai. Very common.

Nummulites Barroni, sp. nov. (Pl. XIV, Figs. 16*a*, *b*, *c*.)

Test lenticular, swollen in the centre, hollowed near the periphery, edge quite sharp. Surface striate and sometimes feebly granulate. Average diameter, 5 mm.; thickness at the centre, 2 mm.; shell with from 4 to 5 whorls; 4 turns in a radius of 2 mm. Septa strongly arched. Central chamber subspherical and very large, one measuring ·75 mm.

This species recalls *N. Rouaulti* by its general shape, but the edge is much sharper, and the thickness at the centre is greater in relative proportion to size.

The three species *N. curvispira*, *N. Rouaulti*, and *N. Barroni* are probably related, and represent a group of the megalospheric type which has a dimorphic relationship with *N. Gizehensis* and its varieties.

This species is named after Mr. T. Barron, F.G.S., who collected the specimens during his work in Sinai, January to June, 1899.

Coll. Geol. Surv. Egypt, No. 3,598, Box No. 13*l*. Mokattam Series (Middle Eocene) : Wadi Khadáhid, Sinai. Common.

ORBITOIDES, d'Orbigny [1847].

Orbitoides* (*Discocyclina*) *dispansa (Sowerby). (Pl. XIII, Figs. 6*c*, 7*c*.)

Lycophris dispansus, Sowerby, 1837 [1840] : Trans. Geol. Soc. Lond., ser. II, vol. v, pp. 327, 718, pl. xxiv, figs. 16, 16*a*, *b*.

Orbitoides dilabida, Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 140, pl. xxix, figs. 7*a-e*.

Schwager records this species under the name of *O. dilabida* from both the Libyan and the Mokattam Series of Egypt; Dr. Carter found it in Scinde, Kutch, and Arabia.

Nearly all our Sinaitic examples are slightly abraded, as if rolled by current agency, and in one of the specimens, No. 4,112, of later age, they are quite fragmentary.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene) : top of Jebel Abyad, south of Wadi Gharandel, Sinai. Frequent. No. 4,112, Box No. 2*l*. (Derived) ? Bartonian Series (Upper Eocene) or ? top of Mokattam Series (Middle Eocene) : beach deposit, Jebel Abyad, Sinai. Rare, broken. No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene) : Jebel Krer, Sinai. Common.

Orbitoides* (*Discocyclina*) *papyracea (Boubée).

Nummulites papyracea, Boubée, 1832 : Bull. Soc. géol. France, ser. II, p. 445.

Orbitoides (*Discocyclina*) *papyracea* (Boubée), Gümbel, 1868 [1870] : Abhandl. M. ph. Cl. k. bayer. Ak. Wiss., vol. x, p. 690, pl. iii, figs. 3–12, 19–29.

O. papyracea (Boubée), Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 139.

O. nudimargo, Schwager, 1883 : op. cit., p. 139, pl. xxix, figs. 8*a-e*.

The specimens in the Sinaitic limestones show every deviation between the forms figured by Schwager as *O. nudimargo* and ordinary specimens of *O. papyracea*, which sometimes have a slightly thicker test. Our examples are seen in section and are generally more or less fragmentary.

O. papyracea has been found in both the Libyan and Mokattam Series in Egypt.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 1*l*. Mokattam Series (Middle Eocene) : top of Jebel Abyad, south of Wadi Gharandel, Sinai. Frequent. No. 3,902, Box No. 15*l*. Libyan Series (Lower Eocene) : Jebel Krer, Sinai. Rare.

Orbitoides* (*Discocyclina*) *ephippium (Schlotheim).

Lenticulites ephippium, Schlotheim, 1820 : Die Petrefactenkunde, p. 89.

Orbitoides (*Discocyclina*) *ephippium* (Schlotheim), Gümbel, 1868 [1870] : Abhandl. m. ph. Cl. k. bayer. Ak. Wiss., vol. x, p. 696, pl. iii, figs. 15, 16. 38, 39.

Orbitoides ephippium (Schlotheim), Schwager, 1883 : Palæontographica, vol. xxx, Pal. Theil, p. 139.

A few characteristic examples of the above species occur in our sections. It was recorded by Schwager from the Mokattam Series of Egypt.

Coll. Geol. Surv. Egypt, No. 4,111, Box No. 11. Mokattam Series (Middle Eocene): top of Jebel Abyad, south of Wadi Gharandel, Sinai. Rare, somewhat fragmentary.

SPECIES DESCRIBED IN THIS PAPER.

1. *Miliolina circularis* (Bornemann). Libyan Series: Jebel Krer.
2. *Alveolina Boscii* (Defrance). Libyan Series: Jebel Krer.
3. *A. decipiens*, Schwager. Libyan Series: Jebel Krer.
4. *Textularia agglutinans*, d'Orbigny. Libyan Series: junction of Wadi Baba and Wadi Shellál.
5. *Bigenerina nodosaria*?, d'Orb. Libyan Series: Jebel Krer.
6. *Bolivina punctata*?, d'Orb. Mokattam Series: Jebel Abyad.
7. *Globigerina bulloides*, d'Orb. Bartonian or top of Mokattam Series: Jebel Abyad.
8. *G. conglobata*, Brady. Mokattam Series: Jebel Abyad.
9. *G. cretacea*?, d'Orb. Mokattam Series: Jebel Abyad. Also Libyan Series: Jebel Krer.
10. *Discorbina rugosa* (d'Orb.). Mokattam Series: Jebel Abyad.
11. *D. globularis* (d'Orb.). Mokattam Series: Jebel Abyad.
12. *Truncatulina umbonifera* (Schwager). Mokattam Series: Wadi Khadáhid.
13. *Rotalia calcariformis* (Schwager). Mokattam Series: Jebel Abyad.
14. *Operculina complanata* (Defrance), var. *canalifera*, d'Archiac. Libyan Series: junction of Wadi Baba and Wadi Shellál; Jebel Krer.
15. *O. complanata*, var. *discoidea*, Schwager. ? Bartonian or top of Mokattam Series: Jebel Abyad.
16. *Heterostegina depressa*, d'Orb. Libyan Series: Jebel Krer.
17. *Nummulites planulata* (Lamarck). ? Bartonian or top of Mokattam Series: Jebel Abyad.
18. *N. Guettardi*, d'Arch. & Haime, var. *antiqua*, De la Harpe. Libyan Series: Jebel Krer.
19. *N. Ramondi*, Defrance. Libyan Series: junction of Wadi Baba and Wadi Shellál.
20. *N. Heberti*, d'Arch. & Haime. ? Bartonian or top of Mokattam Series: Jebel Abyad. Also Libyan Series: Jebel Krer.
21. *N. variolaria* (Lamarck). ? Bartonian or top of Mokattam Series: Jebel Abyad.
22. *N. subdiscorbina*, De la Harpe. Mokattam Series: Jebel Abyad.
23. *N. Gizehensis* (Forskál), var. *Ehrenbergi*, De la Harpe. Mokattam Series: Jebel Safariat.
24. *N. Gizehensis*, var. *Lyelli*, d'Arch. & Haime. Mokattam Series: Jebel Safariat.
25. *N. Gizehensis*, var. *Pachoi*, De la Harpe. Mokattam Series: Jebel Abyad; Jebel Safariat; Wadi Khadáhid.
26. *N. curvispira*, Savi & Meneghini. Mokattam Series: Jebel Abyad; Wadi Khadáhid.
27. *N. Barroni*, sp. nov. Mokattam Series: Wadi Khadáhid.
28. *Orbitoides dispansa* (Sow.). ? Bartonian or Mokattam Series: Jebel Abyad. Libyan Series: Jebel Krer.
29. *Orbitoides papyracea* (Boubée). Mokattam Series: Jebel Abyad. Libyan Series: Jebel Krer.
30. *O. ephippium* (Schlotheim). Mokattam Series: Jebel Abyad.

EXPLANATION OF PLATE XIII.

FIG. 1.—*Nummulites subdiscorbina*, De la Harpe. Mokattam Series: in nummulitic limestone top of Jebel Abyad, Sinai. No. 4,111. × 16.

FIG. 2*a*.—*Nummulites planulata* (Lam.).
FIG. 2*b*.—*N. variolaria* (Lam.).
? Bartonian or ? Mokattam Series: in foraminiferal limestone, Jebel Abyad, Sinai. No. 4,112. × 12.

FIGS. 3*a*, 4*a*.—*Operculina complanata* (Defr.), var. *canalifera*, d'Archiac.
FIGS. 3*b*, 4*b*.—*Nummulites Ramondi*, Defrance.
Libyan Series: in dolomitized foraminiferal limestone, junction of Wadi Baba and Wadi Shellál, Sinai. Nos. 4,135 and 4,113. × 16.

FIG. 5.—*Nummulites curvispira*, Savi & Meneghini. Wadi Khadáhid, Sinai. No. 3,598. × 4½.

FIGS. 6, 7.—Libyan Series: foraminiferal limestone, Jebel Krer, Sinai. No. 3,902. 6*a*, *Alveolina Boscii* (Defrance); 6*b*, *Nummulites Guettardi*, d'Arch. and Haime, var. *antiqua*, De la Harpe; 6*c*, 7*c*, *Orbitoides dispansa* (Sow.); 7*a*, *Heterostegina depressa*, d'Orb.; 7*b*, *Bigenerina? nodosaria*, d'Orb. × 16.

EXPLANATION OF PLATE XIV.

FIG. 1.—*Miliolina circularis* (Bornemann). Transverse section. Libyan Series: Jebel Krer, Sinai. No. 3,902. × 30.

FIG. 2.—*Alveolina decipiens*, Schwager. Transverse section. Libyan Series: Jebel Krer, Sinai. No. 3,902. × 15.

FIG. 3.—*Textularia agglutinans*, d'Orb. Longitudinal section. Libyan Series: junction of Wadi Baba and Wadi Shellál, Sinai. No. 4,113. × 15.

FIG. 4.—*Bolivina punctata?*, d'Orb. Longitudinal, peripheral section. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIG. 5.—*Globigerina bulloides*, d'Orb. Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIG. 6.—*Globigerina conglobata*, Brady. Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIG. 7.—*G. cretacea?*, d'Orb. Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIG. 8.—*Discorbina globularis* (d'Orb.). Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIG. 9.—*D. rugosa* (d'Orb.). Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 30.

FIGS. 10*a*, *b*.—*Truncatulina umbonifera* (Schwager). Mokattam Series: Wadi Khadáhid, Sinai. No. 3,598. × 30.

FIG. 11.—*Rotalia calcariformis* (Schwager). Section of test. Mokattam Series: Jebel Abyad, Sinai. No. 4,111. × 15.

FIG. 12.—*Operculina complanata* (Defrance), var. *canalifera*, d'Archiac. Libyan Series: junction of Wadi Baba and Wadi Shellál, Sinai. No. 4,135. × 3.

FIG. 13.—*O. complanata* (Defr.), var. *discoidea*, Schwager. ? Bartonian or ? Mokattam Series: Jebel Abyad, Sinai. No. 4,112. × 3.

FIG. 14.—*Nummulites Gizehensis* (Forskål), var. *Lyelli*, d'Archiac & Haime. Section on the fifth and sixth whorls. Mokattam Series: Jebel Safariat, Sinai. No. 4,163. × 15.

FIG. 15.—*Nummulites Gizehensis* (Forskål), var. *Ehrenbergi*, De la Harpe. Section on the eleventh and twelfth whorls. Mokattam Series: Jebel Safariat, Sinai. No. 4,163. × 15.

FIGS. 16*a*, *b*, *c*.—*Nummulites Barroni*, sp. nov. 16*a*, superficial aspect of test; 16*b*, edge view; 16*c*, median section. Mokattam Series: Wadi Khadáhid, Sinai. No. 3,598. × 2.

NOTICES OF MEMOIRS.

THE MUSEUMS ASSOCIATION: ELEVENTH ANNUAL MEETING, CANTERBURY, JULY 9–12, 1900. President, Henry Woodward, LL.D., F.R.S., F.G.S., V.P.Z.S, P. Pal. Soc., of the British Museum (Natural History); Treasurer, Alderman W. H. Brittain, J.P., F.R.G.S. (Museum, Sheffield); General Secretary, E. Howarth, F.R.A.S., F.Z.S. (Museum, Sheffield).

THIS useful and deservedly successful Association—supported by the presence of the Right Rev. the Bishop of Dover; the Very Rev. the Dean of Canterbury; the Rev. Canon Routledge; the Worshipful the Mayors of Canterbury and of Dover; the Deputy-Mayor, Mr. Alderman Mason, J.P.; by F. Bennett-Goldney, Esq. (Hon. Curator of the Royal Museum, Canterbury); Mr. Sebastian Evans, M.A., LL.D.; Mr. Stephen Horsley,

Sheriff; Mr. Henry Fielding, Town Clerk; and fifty Delegates and Associates from various Museums throughout the country—opened its public proceedings on Tuesday morning at 10 a.m. with an address of welcome by His Worship the Mayor of Canterbury, Alderman Geo. J. Collard, J.P.

Alderman W. H. Brittain—in the absence of the outgoing President of the Association—then proposed the election of Dr. Henry Woodward, F.R.S., of the Natural History Branch of the British Museum, as President for 1900–1901, and paid an earnest tribute to that gentleman's work in connection with Museums.

The election having been carried unanimously,

Dr. Woodward rose to return his thanks and proceeded to read his Presidential address.

It was, he said, a happy omen—he had almost said inspiration—which led the founders of that Association to invite its organizing Committee, twelve years ago, to meet in the ancient *Eboracum*, the city of "the White Rose of York," once the capital of Roman Britain, which, blazoned down the long roll of history for eighteen hundred years, still firmly stood its ground, like some ancient warrior, all scarred and weather-beaten by time, by wars, and by revolutions, a landmark in our history and a light to science. Such was the fair archiepiscopal city of York, the birthplace of the Museums Association, which in 1831 gave origin to the great British Association for the Advancement of Science, and still earlier (1822) founded the Yorkshire Philosophical Society. After visiting Liverpool, Cambridge, Manchester, London, Dublin, Newcastle, Glasgow, Oxford, Sheffield, and Brighton, the members of the Museums Association had set out this year upon a pilgrimage to Canterbury, the Mother-City of the English people—the "Cant-wara-byrig," the capital city of the "Cant," the "Angul," or corner of Britain nearest to the Continent, towards which the immigration of those Belgic tribes into Britain in pre-Roman times was directed, and the later invasion of Julius Cæsar, B.C. 54. The Cathedral, which dated back to A.D. 602, was recovered by St. Augustine, its first Archbishop, there having been, it was said, a church already on the spot built by early Roman Christians. Like York, Canterbury had been an archiepiscopal See from the earliest times to the present day, and many of its primates lay buried within its precincts.

But it was not his duty to descant upon the merits of their present happy meeting-place, or to attempt to record its history. Those were matters he could safely leave in far abler hands, for among their Vice-Presidents he saw the names of the Very Rev. the Dean of Canterbury, the Worshipful the Mayor (Mr. Alderman George Collard, J.P.), Mr. Alderman Mason, J.P., and many other gentlemen, including Mr. F. Bennett-Goldney, the Honorary Curator of the Royal Museum, Canterbury. They had also to be thankful for the assistance of Mr. Henry Mead as Local Secretary. Upon the kindness and hospitality of those gentlemen during their visit, he felt sure they might safely rely, and indeed their programme held out many agreeable promises of pleasant visits both here

and in Dover during their brief sojourn in Kent. The newly-elected President thanked the members for the high compliment they had paid him in installing him in that office, and proceeded to refer to his forty-two years' association with the British Museum, and to the many changes and developments which had taken place there during that period under the management of its numerous present and past officers and assistants. Referring to various means by which additional interest may be introduced into public museums, the speaker said that among the objects commenced to be carried out by the new Director, Professor E. Ray Lankester, was the formation of a museum to illustrate animals under domestication. The Director hoped to be able to obtain examples of the various breeds of animals which were the result of the invention of man—giving rise to what in Nature would almost amount to the "origin of species." But it did not appear that those varieties could ever remain permanent without artificial environments. All the immense varieties of the dog, for example, would speedily disappear or degenerate into mongrels if not strictly preserved by man. The same was true of the various breeds of fancy pigeons; if neglected, the offspring would again revert to the common blue rock pigeon from which they had sprung. Breeds of horses and cattle, when removed from care and the influence of domestication, were also found to lose their distinctive points of difference, and to revert to the common wild form best adapted to its surroundings. Professor Lankester hoped to secure examples of some of those, and photographs of others to serve as records, as a basis for future investigations. Dr. Woodward pointed out that in order that they might benefit permanently by the great advances made of late in natural knowledge, they must be prepared to make great changes, and sacrifice many cherished ideas, and might find themselves travelling along new lines, guided by new lights, or, perchance, might have to make their own lines, and even to advance under hostile opposition to carry out their new ideas. This led the President to enter into various details of museum arrangement, in which he suggested several improvements and gave results of other scientists' and naturalists' observations in this direction. Dr. Woodward particularly referred to the most valuable set of publications of Monographs, Catalogues, and Guides, issued by the authority of the Trustees of the British Museum, of which he exhibited some examples on the table. Also to the use of printed descriptive labels for all the more important groups of animals, and for all objects of special interest and novelty exhibited to the public in the Museum Galleries.

The President dealt with the subject of arranging specimens in museums and the difficulty of displaying recent and fossil forms together in one series. He referred to an earlier discussion of this subject which took place at the British Association Meeting in Manchester in 1887. In adopting such a radical alteration in the arrangement of objects, first, there was 'public opinion' to be considered; secondly, in a great public museum like that of the

British Museum of Natural History there was the organization of the staff, which, like the collections, was divided into departments; thirdly, there was the cost of making such alterations, which was very great; and fourthly, there was the matter of convenience.

"*Public opinion*," said Dr. Woodward, "is, I find, very largely in favour of keeping the Geological and Zoological Collections distinct from one another, principally because the people who use the collections are still interested in them according to the special line of research in which they are engaged, and the books which they have been reading. They come expressly to see the Birds, or the Beetles, or Butterflies, the African Antelopes, or Recent Shells, and don't want to see the fossil ones. Or, again, they are interested in *Ammonites*, or in *Trilobites*, or Fossil Fishes, and wish to see what we have exhibited of one or other of these. For, after all, the human intellect is restricted, and we cannot, many at least of us, hope to attain to the wisdom of Solomon, who discoursed of trees from the cedars of Lebanon to the hyssop that springeth out of the wall, and spake also of beasts, and of fowls, and of creeping things, and of fishes. The necessities arising out of the greatness of the subject has made most of us *specialists*, and we are, as a rule, content to know one group fairly well. As a consequence, we rarely, nowadays, meet with the all-round Naturalist who has a wide knowledge of most branches of Zoology and of Botany. Many of the members of this Museums Association have, however, compulsorily, to keep up such an all-round acquaintance with Natural History, and not unfrequently to undertake the intelligent arrangement of an Art-Gallery and perhaps a Gallery of Antiquities as well. They have, in fact, to be more learned than the Professors of Natural History in the Queen's Universities, who less than 50 years ago were required to lecture on Geology, Mineralogy, Botany, and Zoology, in all their varied branches! and to give demonstrations also to their classes in the field.

"The organization of a Museum into Departments, each under its own special head, is almost fatal to any scheme of amalgamation, and although under the late Sir William Flower, and the present Director, Professor Ray Lankester, much has been done towards breaking down the hard lines of demarcation, still the Departments of Palæontology and Zoology remain as such to the present day.

"The late Director commenced in 1896 to remodel the Zoological Department, working specially at the *Mammalia*, up to the time of his retirement in September, 1898, and with the active co-operation of Mr. Richard Lydekker, F.R.S. (who has continued the task down to the present time). Still the great work remains unfinished.

"Sir William Flower's last efforts were devoted to complete the exhibition of Cetacea in the new whale-room, which contains models, skins, and skeletons of thirty-eight of these huge marine mammals. The present Director has just added *all the fossil forms*, so that in this one group the biologist is able to see the living and extinct members of the Cetacea placed side by side, and can realize how far such a plan is a success.

"In the other groups of the Mammalia Mr. Lydekker has been unable to introduce the whole of the fossil forms, and has been content to indicate their existence by drawings, by coloured casts, or by parts of specimens, wherever he could make room for them. Explanatory labels have been introduced in each group, and skeletons also of each type of mammal. Coloured maps showing the geographical distribution of each family are also placed with them. To do all this the actual number of exhibited specimens has of necessity been *greatly reduced.* This *limited exhibition* of recent and extinct forms together in one series had been advocated by me in 1887, and may be seen carried out, as far as I have been able to obtain specimens, in the palæontological galleries under my care."

o o o o o o o o

Dr. Woodward referred to the two great epoch-making events which had so widely affected all the sciences, and which saw the light just forty-two years ago, namely, the discoveries in prehistoric archæology, by which the age of man has been carried back into Newer Tertiary time, and the extinct Mammalia had been shown to have survived down to the human period, and to have been contemporary with early man and with many of the surviving forms of animals of to-day; uniting the latest chapter of geological history to the oldest records of our race, and joining the sciences of Geology and Archæology together. Secondly, the enunciation at the same period of Darwin's origin of species and the doctrine of evolution, which linked into one the whole chain of life from the earliest records in Archæan Rocks to the full tide of existences which now surround us.

o o o o o o o o

The President, in conclusion, advocated the desirability of the publication by the Association of a handbook giving an account of every provincial museum throughout the country, with full particulars as to each, not only as to its officers, organization, and its plan of arrangement, but also what were the chief features of its exhibits, and especially to print any records concerning 'types' and 'figured specimens' preserved in its collection and any other particulars of general public and scientific interest.

REVIEWS.

I.—The Eighth International Geological Congress, Paris, 1900. Livret-Guide des Excursions en France du viii^e^ Congrès Géologique International. Avec 372 figures dans le texte et 25 planches. (Paris, 1900.)

THE "Comité d'organisation du viii^e^ Congrès Géologique International," under the presidency of the venerable Professor Gaudry, has just issued a "Livret-Guide des Excursions en France du viii^e^ Congrès Géologique International." To judge from this publication, the preparations for the impending Congress, which is to meet at Paris from the 16th to the 28th August, have been

exceedingly well made. The "Livret-Guide" forms a bulky octavo volume of over 900 pages, with no less than 372 beautiful text-figures and 25 plates (geological maps, sections, views, etc.).

The introduction contains notices of the geological, mineralogical, and palæontological museums and collections of Paris — Muséum d'Histoire Naturelle, Ecole des Mines, Sorbonne, Ecole Libre des Hautes Etudes Scientifiques, Collection Pellat—drawn up by the respective keepers.

The choice of the regions to be visited has been made in such a manner that the Guide contains, as a matter of fact, a description of all the 'terrains' of France, thus giving a summary of our actual knowledge of the detailed geology of the country. So that this book will be welcome not only to the members of the Congress, whether excursionists or not, but for several years to come it will remain a useful geological 'Baedeker' of France.

There will be two categories of excursions, 'Excursions générales' and 'Excursions spéciales.' In the latter the numbers are limited to twenty, being intended for specialists only, who are supposed to be at the same time good walkers and not to consider comfort as the primary condition of a scientific excursion. The following are the 'Excursions spéciales':—

August 31 to September 9: Alps of the Dauphiné and Mont-Blanc (Directors, MM. Marcel Bertrand and W. Kilian).
August 6 to 14: Aquitaine (Dir., M. Ph. Glangeaud).
August 6 to 14: Ardennes (Dir., M. Gosselet).
August 30 to September 6: Tertiary basins of the Rhône (Dir., M. Depéret).
August 4 to 14: Bretagne (Dir., M. Ch. Barrois).
August 29 to September 4: Caves of the Causses (Dir., M. E. Martel).
August 3 to 9: Gironde (Dir., M. E. Fallot).
August 30 to September 12: La Mure, Dévoluy, Diois, Valentinois (Directors, MM. Lory, Paquier, Sayn).
August 9 to 14: Mayenne (Dir., M. D. P. Oehlert).
August 11 to 14: Miocene of Touraine (Dir., M. G. Dollfus).
August 29 to September 6: Montagne-Noire (Dir., M. Bergeron).
August 29 to September 6: Mont-Dore (Dir., M. Michel Lévy).
September 11 to 20: Mont-Ventoux and Montagne de Lure (Directors, MM. W. Kilian and Léenhardt).
August 29 to September 8: Morvan (Directors, MM. Vélain, Péron, and Bréon).
August 31 to September 9: Pelvoux and Briançonnais (Dir., M. P. Termier).
September 3 to 8: Picardie (Directors, MM. Gosselet, Ladrière, and Cayeux).
September 23 to October 2: Provence (Directors, MM. Marcel Bertrand, Vasseur, and Zürcher).
August 4 to 14: Pyrenees—crystalline rocks (Dir., M. A. Lacroix).
August 30 to September 8: Pyrenees—sedimentary formations (Dir., M. L. Carez).

September 7 to 11 : Secondary and Tertiary formations of the Basses-Alpes (Dir., M. E. Haug).

August 11 to 14 : Turonien of Touraine and Cénomanien of the Mans (Dir., M. de Grossouvre).

Under the heading 'Excursions générales' are (1) three large excursions, viz. :—

August 29 to September 7 : Coal-basins of Central France (Directors, MM. Fayol and Grand'Eury).

August 30 to September 8 : Primary and Secondary formations of the Boulonnais and Normandy (Directors, MM. Gosselet, Munier-Chalmas, Pellat, Rigaux, Bigot, and Cayeux).

August 29 to September 15 : Central Massif of France (Directors, MM. Michel Lévy, Marcellin Boule, G. Fabre, and E. A. Martel).

(2) Short excursions which will enable members to visit, during the Congress, the Tertiary fossiliferous formations of the neighbourhood of Paris.

From the dates given above it will be seen that the excursions take place *before, during,* and *after* the Congress. The directors of the excursions are the authors of the respective notices on the same, which are issued in twenty-three separate fascicules for the convenience of the excursionists.

In connection with the above it may be mentioned that at the last meeting of the Geological Society of London on June 20, a letter was read from Professor Gaudry, the President of the Organizing Committee of the Congress, to the Foreign Secretary of the Geological Society, conveying a very warm and cordial invitation to the Fellows of the Geological Society to attend the Congress, and assuring to them a hearty welcome from their geological brethren of France. It is to be hoped that this generous invitation will find a ready response from our British Geologists.

II.—Catalogue of the Fossil Bryozoa in the Department of Geology, British Museum (Natural History). The Cretaceous Bryozoa. Vol. I. By Dr. J. W. Gregory, D.Sc., F.G.S. 8vo ; pp. xiv, 457, 17 plates, text illustrated. (London : printed by order of the Trustees of the Museum, 1899.)

FOUR years ago we had the pleasure of noting (Geol. Mag., 1896, p. 378) the first of what it was hoped might be a series of Catalogues of the Fossil Bryozoa in the national collection. That volume, also by Dr. Gregory, dealt with the Jurassic forms, which it was seen would supply the key to those that came after. Now we have before us the first instalment of the Cretaceous Bryozoa. The work is on the same lines as its predecessor, with such changes in nomenclature (e.g. Diastoporidæ for Tubuliporidæ) as experience has shown to be necessary, and is severely technical, consisting as it does of descriptions of the species, with discussions as to synonymy, and so on. The general introduction to the Cretaceous Bryozoa, with other interesting questions, such as lists of localities with their

horizons, have been deferred for a second volume, and we can only hope that though, greatly to the regret of his colleagues at the Museum, Dr. Gregory has taken himself to fresh fields, the work he has so ably begun may yet be carried to a successful end.

The Bryozoa are notoriously a difficult group, though they are a most fascinating study owing to the beauty of their forms, which must strike even the most casual observer on turning over the admirably executed plates which conclude the volume.

CORRESPONDENCE.

FORMATION OF MARITIME PEAT.

Sir,—It may interest some of the readers of this Magazine to learn that a remarkable illustration of the mode of formation of beds of maritime peat is at present to be seen on the shore in a small bay near the Bucket Rocks to the east of this town. During a heavy flood one day late in the past autumn great quantities of leaves were washed into the Tweed from the numerous woodlands, parks, and hedgerows adjoining its banks, and in course of time were drifted out to sea. A south-east wind prevailed at the time, and the flotilla of leaves, on reaching the quieter water of the sea off the river mouth, were gently wafted shorewards in the direction of the sheltered bay referred to. As they floated they were evidently first sorted out, in accordance with their buoyancy, and then were quietly deposited at the foot of the cliff as the tide fell. They form a sodden mass of leaves quite five feet in thickness at several places, which extends along the shore for several hundred yards.

An old resident, long acquainted with the coast there, tells me that the same thing happens almost every year; but that each year's deposit is generally washed seaward again, sooner or later, after it has been laid down.

As might be expected from the nature of the deposit, the constituents of which have been arranged solely with reference to their powers of flotation, it includes a small percentage of dried materials which the sea-water has floated from various parts of the shore. Bits of paper, straws, dried fronds of *Fucus vesiculosus* and *F. serratus*, coated with *Spirorbis*, and pieces of *Laminaria* encrusted with *Membranipora*, occur in small proportion, and there are a few fragments of corallines. *Talitrus locusta*, both dead and living, is rather common.

The mass is not divided by any beds of mud or sand. The general aspect of the deposit differs but little from that of such beds of maritime peat as occur, for example, at Elie in Fifeshire and at Maryport in West Cumberland, both of which are usually regarded as evidences of former changes of level of the land. Yet it must be obvious, from a consideration of the facts above noted, that similar deposits must frequently be laid down in the vicinity of large rivers, in quiet nooks both at the sea-level and beneath it, if the vegetable remains in the latter case have soaked long enough to become water-logged.

J. G. Goodchild.

Berwick, *July* 4, 1900.

OBITUARY.

JOHN YOUNG, LL.D., F.G.S.

BORN 1823. DIED MARCH 13, 1900.

JOHN YOUNG was born at Lennoxtown, in the parish of Campsie, 1823. His father, Thomas Young, was employed in the wright-shop of Lennox Mill, the bleaching-field and calico-printing works of Dalglish, Falconer, & Co. When 10 years old he was taken from school to be a message-boy in the Bleachfield. This was before the employment of children was ameliorated and regulated by the Legislature; and then he was taken on in the Mill, where 16 hours a day (at sixpence a day and a penny an hour for over-work), whether in the hot or cold works (both extreme), were more than he could bear; and his mother took him away. Afterwards he was apprenticed for seven years to print-cutting.

He was in the employment of the firm for 26 years, until he went to live in Glasgow in 1859, but before then he utilized what little time his hard work allowed him for study, attending the Mechanics Institute and reading what books he could get to see on Geology, his favourite science, and becoming well known among geologists.

In 1855 the British Association met at Glasgow, under the presidency of the Duke of Argyll, and a collection of the rocks and fossils of the West of Scotland was to be an important feature at the meeting. Mr. Robert Dalglish, partner in the Bleachworks, etc., knew of John Young's geological taste and competence, and arranged to let his employé go to Glasgow to superintend and classify the collection. For five months he was engaged on this work, and was brought into contact with some of the leading geologists of the time. So thoroughly qualified was he for this task, that shortly afterwards the Senatus of Glasgow University offered him the position of Keeper of the Hunterian Museum. In 1859 he removed to Glasgow with his wife and young family, and entered on his new duties, living at the Old College in the High Street of Glasgow.

He successfully fulfilled an onerous duty when the College of Glasgow was removed from the High Street to Gilmorehill. He carefully packed and removed the thousands of specimens—pathological, physiological, and antiquarian—contained in the Hunterian Museum, arranging and classifying them in their new location, with the co-operation of his colleague, Professor John Young, M.D., the Head Keeper of the Museum.

The Campsie district in Stirlingshire, between Glasgow and Stirling, especially around Lennoxtown, his birthplace (about seven miles north-east of Glasgow), had always attracted John Young; indeed, at an early period he studied its features and its geological structure assiduously and with success. He made himself acquainted with all the natural and artificial exposures of its rocks and strata, learning the mineralogical nature of the greenstones and ash-beds of the trap-formation, and the fossil contents of the sedimentary limestones, shales, and sandstones, some of which, equivalent to the "Calciferous Sandstone Series," are intercalated with the trappean rocks.

From the Old Red Sandstone, lying below, he carefully noted the sequence of the several members of (1) the "Calciferous Sandstone Series," including the Ballagan Limestone Series and the Trap Series; and (2) the several members of the "Lower Limestone Series," belonging to the great Lower Carboniferous Formation, and equivalent in part to the Mountain Limestone of England. The successive members of this "Lower Limestone" group in ascending order and divisible by their constitution and their fossils, he defined as that of Mill Burn, of Balgrochen Burn, of Balglass Burn, of Craigen Glen, of the Main Limestone and Coal, of the Hosie Limestone, and of Corrie Burn. The Balquarhage Series, belonging to the "Upper Limestone," also occurs.

In the above-mentioned groups of strata there are several seams of coal, of not very good quality. There are some good cement-stones; and a large proportion of the Campsie shales contain useful ironstone. Others of them are good oil-shales, in which the crowded organisms, such as Entomostraca, have supplied, as he shows, the hydrocarbon. Marine shells are abundant in many of the strata, but in some limestones and shales they are wanting, only remains of plants, fishes, and Entomostraca remaining in evidence of what is regarded as estuarine conditions of these particular deposits. By further research John Young and his colleagues elucidated the relationship of these interesting strata of Campsie to those of other parts of Western Scotland and elsewhere. Faults, causing a displacement of the strata, were carefully observed by John Young in the Campsie valley (the greenstone dyke at Milton for instance), and the great Eddlewood fault in the Lanarkshire Coalfield.

The uppermost deposits in the region referred to belong to the Erratics of the Quaternary period, such as the boulder-till and the sands and gravels that were washed out of old moraines; and these have been cut into and variously modified by river-action since the last uprise of the country. Surface scratchings and other glacial markings are frequent. A striking monument to John Young's industry and acumen in glacial geology exists in the Hunterian Museum, where he accumulated and laid out carefully for inspection a well-selected and extensive series of boulders and striated stones (190 varieties) excavated from the local Boulder-till in digging the foundations of the noble University on the crown of Gilmore Hill. In the Museum there they now constitute a valued "memorial of the great variety of travelled rocks found on the site," as John Young intended (Trans. Geol. Soc. Glasgow, vol. iii, 1871, p. 304). Indeed, he showed that the hill itself comprises a characteristic succession of the Lower and Upper Limestone Series, mentioned above as having been elucidated by his researches at Campsie and elsewhere.

In collecting and determining the multitude of fossils from the Carboniferous strata, not only of the vicinity of Glasgow, but throughout the rich middle basin of Scotland, from the Firth of Clyde to the Firth of Forth, he greatly advanced his favourite science. He gained much experience in the discrimination of Lamellibranchiata and Brachiopoda, studying their shell-structure minutely under the microscope. Polyzoa were frequently described